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A REVIEW OF THE THERMIC MOTORS EXHIBITED IN PARIS, IN 1878.

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The eminent physicist, M. Hirne, has discovered, experimentally demonstrated and measured, the thermic influence of the sides of the steam engine cylinder. Perhaps he suspected that it was caused by the condensation during expansion. But he proved that there was a continual exchange of calories between the sides of the cylinder and the steam, throughout the time of that mysterious transformation in which heat disappears in quantity proportional to the mechanical work performed.

In a review which professes a practical bearing only it seems inopportune to bring forward historical proofs of this fact; they will be reserved for another time and place.

The skillful and numerous experiments of M. Hirn and his disciples, have led to the determination in a rigorous manner of the economic results to be obtained from steam jackets, from superheating, from prolonged expansion etc., etc., and constructors have drawn valuable practical conclusions from these results.

But an economy which appears considerable when expenditure of steam is alone considered, diminishes singularly when we seek for a corresponding economy in the fuel. This indicates that the process employed in steam engines for conversion of heat into mechanical work is vicious in principle.

I hold to be able to prove this assertion, however discouraging it may seem, especially because I shall have before long to lavish praises upon those courageous constructors who have applied so much knowledge and sagacity to the improvement of this most powerful auxilliary of civilization, without however obtaining results worthy of their efforts.

So far only as the different elements act to exert an influence upon the consumption of steam, is it necessary to distinguish between the phenomena produced in the boiler, and those that take place in the cylinder. It is necessary to determine the weight and composition of the mixture of the water and steam which play so important a role, without occupying ourselves with the question of the origin of the steam. But to him who makes daily use of the complete machine, boiler and engine, the important question relates to the *consumption of fuel*, and it becomes important consequently to take it into serious consideration, as well as the mode of production and the mode of transmission of the heat to the intermediate body, the mixture of steam and water.

If we compare the economy that it is possible to realize in the *employment of*

heat in the engine, with that which it is possible to attain in the *production of heat in the fire place*, we readily discover a marked advantage in favor of this latter part of the apparatus.

We proceed to demonstrate the above by calculation.

Suppose we burn under a boiler a coal of which analysis affords the following composition:

Carbon	$0^k.915$
Hydrogen	0 .035
Oxygen	0 .026
Ash	0 .024
Total	$1^k.000$

We will take for the calorific powers of carbon and hydrogen 8,060 and 34,460 respectively. We will admit furthermore, in common with most authors, that an amount of hydrogen equal to an eighth part of the oxygen present ($=0^k.00325$) is already combined with the oxygen, and consequently can not aid in the production of heat by combustion. In other words the amount of hydrogen available for fuel is only $0^k.035 - 0^k.00325 = 0^k.03175$. The calorific power of the fuel is then:

For the hydrogen
$0.01375 \times 34460 = 1094$ cal.

For the carbon
$0.915 \times 8060 = 7375$ cal.

Total calorific power 8469 cal.

We will next determine the amount of air required to complete the combustion.

Each kilo of carbon demands $\frac{8}{3}$ kilo of oxygen to burn it. Each kilo of hydrogen requires 8 kilos of oxygen.

We have then:

For the carbon
$0.915 \times \frac{8}{3} = 2^k.440$

For the hydrogen
$0.01375 \times 8 = 0.254$

Total $2^k.694$ for oxygen.

In 9 kilograms of air there are two of oxygen; the weight of air necessary for the combustion of a kilogram of this fuel will be $\frac{9}{2} \times 2.694 = 12^k.123$.

The products of the above combustion will be:

Carbonic dioxide
$0.915 + 2.440 = 3^k.355$
Vapor of water
$0.03175 + 0.254 = 0.28575$
Moisture previously in the coal
$0.00325 + 0.026 = 0.02925$
Nitrogen of the air $= 9.429$
Ash $= 0.024$

Total $= 13^k.123$

But if to burn solid fuel we admit only just sufficient air for perfect combustion, the burning is certainly incomplete, and a quantity of carbonic monoxide remains unconsumed.

In order to insure complete combustion of an average coal where a chimney is provided for draft, there is required an excess of air equal to about two-thirds of the amount which is chemically necessary. In the above example, therefore, about eight kilograms of air must be converted in with the products of the combustion, making a total of $13^k.123 + 8 = 21^k.123$.

The amount of heat necessary to raise the temperature of these products of the combustion of one kilogram of coal, through one degree, is determined by multiplying the weight of each of these substances by its specific heat, and taking the sum of the products.

For Carbonic Dioxide
$3^k.355 \times 0.217 = 0.7280$ cal.
" Vapor of water
$0.315 \times 0.475 = 0.1496$ "
" Nitrogen $9.429 \times 0.245 = 2.3101$ "
" Ash $0.024 \times 0.200 = 0.0048$ "
" Air unburned
$8.000 \times 0.238 = 1.9040$ "

Total 5.0965 cal.

or a little more than five calories.

The above calculations relating to the fire assume an ideal condition which is unfortunately tacitly adopted, without closely defining it. This renders it necessary for us to explain what is involved in this ideal condition—this ideal *regimen* of the furnace.

The sides of the fire-place receive heat either by contact of the gaseous products of combustion or by radiation. But they emit heat also towards the interior of the fire-box and the flues. The heat penetrates to a certain depth

in the sides of the furnace, but if these latter are made of properly refractory materials, the heat is not conducted to the exterior surface.

When the fire is first started these materials become heated to higher and higher temperatures, and to greater depths in their thickness. As the temperature rises, they radiate an increasing amount of heat, while the amount absorbed in a given time becomes less. It necessarily follows that the time soon arrives in which the quantity of heat received from the products of combustion by the sides of the furnace, is equal to that returned by the sides to the gases. Then the ideal regimen is established, and the heat developed by the combustion has no other effect than to raise the temperature of the products of the combustion.

Doubtless these gases are cooled by their contact with these surfaces, but at their origin in the fire there is a time when the heat of the combustion takes effect only in raising the temperature of these gaseous products.

When this *regimen* is once established, the 8469 calories developed by the combustion of a kilogram of the combustible will be employed only in augmenting the temperature of the twenty-one kilograms of products, and will effect a rise of one degree of temperature for an expenditure of each five calories. In other words, in the case we are considering, there will be a difference in the temperature of the materials put on the fire, before combustion and after it of

$$\frac{8469}{5.0965}=1661 \text{ degrees.}$$

We have then, by burning a kilogram of coal, produced 8469 calories, and this heat applied entirely to the products of combustion has raised their temperature 1661 degrees.

Let us now assume, first, that the absolute zero of temperature is 273° below the zero of the centigrade scale; second, that the temperature of the materials, before burning is that of the outside air; say 15°. Then the *absolute* temperatures of the outside air and the combustion products are respectively:

$$273°+15°=288$$
$$273°+1676°=1949°.$$

The gases, therefore, in the fire-pits of our steam engines, may be considered as sources of heat, maintained, what ever the losses, at a constant absolute temperature of 1949°.

We will call bodies *cold* that are at the temperature of the surrounding air, whatever the source from which their heat (assumed at 288° of absolute temperature) is obtained.

If we transfer 8469 calories from a hot body to a cold one, employing the greatest possible amount in producing work, by aid of a perfect engine, we get by known laws of thermodynamics

$$8469\times\frac{1949-288}{1949}$$
$$=8469\times0.852=7216 \text{ cal·}$$

which will each afford 425 k. m. of work,

and also $8469\times\frac{288}{1949}=1253$ calories,

which are not converted, but are expended on the cold body.

The 7216 calories utilized as work produce $7216\times425=3066800$ kilogrammeters.

This is the maximum of work that can be obtained from 8469 calories between the absolute temperatures of 1949° and 288°. In other words, by burning a kilogram of coal we have at our disposal 3066800 kilogrammeters of work, assuming that we employ our means to the utmost.

How do we employ this result?

A steam engine that affords a horse-power per hour for each kilogram of coal burned (that is, yielding 270 000 k. m.) may be classed among the most economical. (I know that results better than this are often claimed, and the claim seems to be justified by experiment, but I refer here to practical results obtained year by year and not to experiments limited to a few hours).

The efficiency of our best engines then is

$$\frac{270\ 000}{3{,}066{,}800}=0.088;$$ less than nine per cent.

What becomes of the other ninety-one per cent.?

Is not a process of utilization of heat which results in a loss of ninety-one per cent., vicious in principle? And if so, where is the fault? In the engine? or

in the boiler? Where shall we apply the remedy for so great a failing?

We will proceed to reply to some extent to these questions.

In order to utilize the total fall of temperature, it becomes necessary to reduce the temperature of the gases in absorbing their work, till their temperature falls from 1676° to 15°. Or if by means of this heat we raise the temperature of another body, it becomes necessary that these products of combustion be cooled with useful effect to the temperature from from whence they started, or 15°.

Now this is impossible with our steam boilers. The products of combustion leave the heated surfaces with a necessary excess of temperature; this excess constitutes the first considerable loss, and is inherent in our methods of employing heat.

In order to fix our attention to a particular case, suppose that a boiler is furnishing steam at six atmospheres pressure, or a temperature of 159°.22 in a continuous manner. Throughout the inside of the boiler then, the surface of the iron is in contact with a fluid at a temperature of 159°. In order that there should be a transfer of heat from outside to inside of the boiler, it is necessary that the external surface be in contact with a fluid whose temperature is above 159°. I believe it is no exaggeration to say that there would be no real transfer of heat if the products of combustion exterior to the boiler were not raised above a temperature of 250°. According to this, the heat of the gaseous products ceases to be useful at 250°.

Then the loss from this source is the heat necessary to raise these gaseous products from 15° to 250°. For each kilogram of fuel this is

$$5.0965(250-15)=1198 \text{ calories.}$$

From the employment, therefore, of gaseous products of a combustion as an intermediate body to furnish heat to the water of a boiler through the metal sides, there results a loss of

$$\frac{1198}{8469}=0.141$$

or fourteen per cent.

Some authors have attributed this loss to the draft of the chimney, and have proposed to replace the chimney by a forced ventilation. They call this fourteen per cent., the "cost of the draft." Aside from the expense of building the chimney (the real cost of the draft), the actual expenditure of heat necessary to accomplish the work of the draft may be neglected.

Of the 8469 calories produced, there is afforded to the water in the boiler, no more than 8469—1198 or 7271 calories; a little less than eighty-six per cent. of the original amount, (0.859).

These 7271 calories are converted into useful mechanical work only through the act of vaporization, and which is brought about at the constant temperature of 159°. The water has then to be introduced against a pressure of six atmospheres, and heated to 159° before any useful effect is obtained from it.

The number of calories expended in introducing the water and raising it to the required temperature, we will call the "expense of feeding the boiler."

As the heat which corresponds to the expense of feeding the boiler, does not contribute directly to the production of useful work, it becomes a second cause of loss, and is to be added to the preceding. We will proceed to estimate it.

In order to raise a kilogram of water to a height of ten meters, and to feed it to a boiler against a pressure of six atmospheres, it is necessary to expend about 62 kilogram meters of work, or about 0.146 calories.

Suppose the temperature of the feed water to be 35°, a fair means for condensing engines. The heat contained at this temperature=35.037 cal., at 159° the heat is 160.835 calories; the difference, 125.8 calories added to 0.146, as above gives 125.944 calories as the expense of feeding the boiler.

Aside from the loss by radiation, there is taken from the heat that is afforded to the water 125.944 cal., as the expense of feeding. From this there is a further amount expended to vaporise the water at the temperature of 159°.22.

This amounts in all per kilogram of water to;

$$606.5+0.305\times 159.22 -35.37=620.625 \text{ cal.}$$

Therefore of the 620 calories supplied, as the cost of feeding is 126, the percentage is

$$\frac{125.944}{620.025}=0.203$$

or a little more than twenty per cent.

Of the 7271 calories introduced into the boiler, there are $7271+.203=1477$ which are also lost so far as mechanical effect is concerned. Only 5794 of the original 8469 remain, equal to 0.684, or about 68 per cent.

We are yet far from having taken all the losses into account. We now call attention to a third cause of loss.

We have seen above, that if there was a fall of temperature from 1676° to 15°, that 1253 calories passed to the cold body without producing useful effect, and that this was a minimum loss, and based upon the hypothesis of a perfect engine. But the employment of steam as an intermediate agent for the pro-production of work, by expenditure of heat, changes the conditions. The highest temperature is now 159° and the lowest 15°, that of the water in the condenser. Under these conditions, the minimum of heat that should pass to the cold body without producing work, is

$$\frac{273+15}{273+159}=0.667:$$

this is to be taken in place of 0.148 which we found before for the temperatures of 1676° and 15°.

The reduction of temperature caused by employing vapor as a second intermediate agent, gives rise to a loss of

$$0.667-0.148=0.519$$

or about fifty-two per cent.

We will estimate this in calories. Of the 5794 calories expended in a perfect engine, between the temperatures of 159° and 15° there are two-thirds or 3863 which pass to the cold body without work. Between the temperatures of 1676° and 15° the loss would be only 1253, a difference of 2610 calories in 8469 or thirty-one per cent.

A recapitulation of the foregoing is herewith presented: An ideal perfect steam engine with a suitable boiler, working under conditions as cited above, and which are practically medium ones; out of an expenditure of 8469 calories can only utilize as mechanical work,

$$5794-3863=1931$$

which is $$\frac{1931}{8469}=0.228:$$

less than twenty-three per cent.

The defective mode of utilizing the heat in steam engines results then in a loss of

$$0.852-0.228=0.624$$

or sixty-two per cent. This is the estimated minimum loss of a perfect engine.

Our best steam engines render 0.088 as we have seen. The total loss then, is $0.852-0.088=0.764$, or more than seventy-six per cent.

Between 0.228 and 0.088 there is a difference of fourteen per cent. This is all that is to be gained by improvements of the steam engine that leave untouched the prime defect. With this defect the consumption of coal will never be less than

$$\frac{0.088}{0.228}\text{ or }0^k.386\text{ per horse-}$$

power per hour. It is evident that the field for improvement is much vaster for him who seeks to perfect the mode of utilizing heat from its origin, than for him who considers only the mechanism of the steam engine. This we believe is the end to be sought by those who seek to improve gas engines or gas furnaces.

As we are to present calculations upon gas engines, we will first seek to determine the least expense that we can hope for in these motors. Then we can judge more easily of the extent of the possible improvements.

It is not easy to get exact statements in regard to the composition of illuminating gas. Its density also depends upon conditions that we do not pretend to consider here. We will take such figures as seem to represent a medium composition and weight.

Carbon	$0^k.605$
Hydrogen	0 .212
Oxygen	0 .077
Nitrogen	0 .106
	$1^k.000$

The weight of a cubic meter at a mean temperature and pressure is $0^k.585$, the same volume of air weighing $1^k.3$.

To determine the calorific power, we deduct from the amount of hydrogen $0^k.0096$, one eighth of the weight of oxygen, as being already combined with

oxygen. We have then for the hydrogen available for fuel, $0^k.2024$. Multiplying the carbon and hydrogen by their respective calorific powers, we get

$0^k.2024 \times 34460 = 6975$ calories.
$0^k.605 \times 8060 = 4876$ "

Total = 11851 "

To determine the quantity of air required, we proceed as in the case of coal.

For Carbon $\frac{8}{3} \times 0.605 = 1^k.613$ oxygen
For Hydrogen $8 \times 0.2024 = 1.619$ "

Total $= 3.232$

The air required being $4\frac{1}{2}$ times this, we have; $14^k.546$ of air for each kilogram of gas.

The products of combustion are;

Carbonic dioxide	$0.605 + 1.613 = 2^k.218$	
Vapor of water	$0.202 + 1.619 = 1.822$	
Nitrogen originally	0.106	11.420
" with the air	11.314	

If the heat of the combustion were entirely employed in augmenting the temperature of the products, this rise of temperature could be deduced by employing the specific heats of the substances as follows:

Car. dioxide	$2^k.218 \times 0.217 = 0.4813$	cal.
Steam	$1.822 \times 0.475 = 0.8655$	"
Nitrogen	$11.420 \times 0.245 = 2.7979$	"
Total	4.1447	"

The augmentation of the temperature is therefore

$$\frac{11851}{4.1447} = 2859°.$$

Such a temperature being too intense, it is necessary to diminish it. The reduction in the Otto-Gas-Engine is brought about by the admission of a liberal supply of inert gas to mix with the combustible. In this engine, which renders good practical results, there are added to $15^k.546$ of the products of combustion, $10^k.793$ of the same composition. Consequently there is a total of $26^k.339$ of gaseous products, which require

$$4.1447 \times \frac{26.339}{15.546} = 7.0222 \text{ calories}$$

to raise the temperature one degree.

Then the rise of temperature in the Otto engine with constant pressure would be

$$\frac{11851}{7.0222} = 1688°$$

In this engine it is not probable that this temperature is attained, because a part of the heat is absorbed by the work during the combustion. Another portion is absorbed without useful effect by the cold water employed about the moving parts to prevent overheating.

But to determine the efficiency of this motor, we must compare it with an ideal engine, which, expending 11851 calories, experiences a fall of temperature of 1688°.

For this purpose we will suppose that the temperature of the cold body, the outside air is at 0°, or 273° above the absolute zero.

A perfect thermic motor would afford in work

$$425 \text{ k m} \times 11851 \times \frac{1688}{1688+273} =$$

4,335,570 kilogrammeters

for each kilogram of gas burned.

It follows that a cubic meter of gas would afford

$$4335570 \times 0^k.585 = 2{,}536{,}308 \text{ k.m.}$$

The Otto engine consumes about a cubic meter of gas for a performance of one horse power per hour; that is, it yields 270 000 kilogrammeters of work for a cubic meter of gas.

Its efficiency then is

$$\frac{270000}{2536308} = 10.64 \text{ per cent.}$$

This is the result as measured by the friction brake; but if we measure by the indicator, as is done in steam engines, the result is considerably modified.

The consumption for each indicated horse-power per hour is only two-thirds of a cubic meter of gas. That is to say, the Otto engine measured by the indicator exhibits a performance of

$$\frac{3}{2} \times 10.64 = 15.96;$$

nearly sixteen per cent., which is about double the efficiency of the steam engine.

If we do not regard the price of the fuel, the gas engine is superior, in point of efficiency, to the steam engine.

Much remains to be done in improving the gas engine. But the margin for improvement is less than in the steam

engine, or than in any motor employing a fluid heated through an envelope, by gaseous products of combustion.

The principal cause of loss in the Otto engine, exists in the high temperature at which the gas is released after its expansion in the cylinder. We have been able to verify the statement that the gases at their exit have nearly 900° of heat. Now if we could expand them to zero, utilizing the heat in external work, we should regain forty-five per cent. Evidently this is practically impossible. But in the steam engine, besides the *practical* impossibility of realizing twenty three per cent., there is the *theoretical* impossibility of ever passing this limit by reason of the mode of employing the heat.

The gas engine in the most perfect form known to-day, is susceptible of great improvement, incomparably greater than can possibly be made upon the steam engine.

COMMON SENSE IN ARCHITECTURE.

From "The Builder."

Paper read at the meeting of the Architectural Association by Mr. COLE A. ADAMS.

Mr. Fergusson, in the admirable introduction to his "History of Architecture," says; "Convenience is the first thing which the practical common-sense of the Aryan seeks, and then to gain what he desires by the readiest and the easiest means." From this ancient Aryan stock John Bull claims descent, and common sense is a very strong article of his creed.

When and wherever architecture has been practiced as a living art, as the outcome of the wants of the people who practice it, especially in those styles and ages which are generally reckoned by the educated as the purest, this quality of common sense is everywhere recognized, as their works are eminently practical and logical. From the rock-hewn cave and rude hut to the stateliest edifice this principle will be found to exist, and though a common-sense building may have no artistic beauty, a building which sets common sense at nought will fail to please the intelligent observer.

Of the æsthetics of architecture I do not propose to treat this evening (except so far as may be necessary to illustrate my meaning), but rather of the practical side and of modern times, as it is difficult in the short time at our disposal to take a very wide range of the subject; but I shall endeavor by illustration and example to point out the necessity of common sense in architecture, and to show that where it is ignored or wilfully omitted that building cannot fulfil the conditions of art.

Common sense is a gift which is not implanted in the breast of every man, and where it is, it must, like every other talent, be cultivated so that it may gain strength by experience. But the man who adopts any profession or trade is expected by those who employ him to exercise this quality, to cultivate it, and bring it to bear upon the work he supplies; and this, more especially, in a profession where those habits known as business ones form a large part. In our calling it is essential, in the interest of our clients and the nature of our business, that we should strive to conduct it on common-sense principles, for any departure from this will lose us respect and influence in the minds of our employers, the mischief arising from which will extend beyond ourselves, and weaken that respect which we should strive to hold in the eyes of the public.

The charge often brought against us as a body is this want of common sense, that we are not practical, and many find a peculiar pleasure in pressing this accusation. Every blunder committed and brought to light in building must be laid at some door, and our accusers are happy if that door has the name of an architect upon it. Charges of ignorance in sanitation, which, at the present time, is exciting, as a science, so much attention, are hurled at us broadcast, and this is done by people who, if they exercised the common-sense maxim of looking before they leaped, would hesitate, and first ascertain whether an architect had been

employed at all on the work which they condemn, and bear in mind that a very large amount of building is carried out quite independently of our services—that by far the larger number of us are lodged in houses provided by the speculative builder, whom it is not incumbent upon me to defend. He is a most useful man to the public, is created and supported by them, provides wares to suit all pockets, and it is, at least, a little unfair to charge him with the faults inherent in the article which he somehow contrives to sell the public for a sum absurdly below what such an article would cost were it made of true metal.

Further, where this charge of want of common sense is brought against us, the question will arise, What is common sense? You think so and so, and I differ from you. On the whole, considering that I make a study of my work, I ought to know best. Such questions as this must and do arise, and it would be impossible to lay down definite rules, and say this work possesses, and this other does not possess, common sense.

It is easy, of course, to quote gross cases in which this quality under discussion does not exist. For instance, a house without a staircase, a living room without a window, a house built without proper foundations, or in the midst of a swamp, and expected to be dry, when no provision has been made to guard against the situation, and so on. Here, perhaps, we should all agree that no defense could be made, and we have no hesitation in saying that the persons responsible for such doings lack common sense.

Let us also take other examples which require a higher perception of this faculty than those just quoted. We have in the present day a rich store of illustrations of the architecture of the past ages, and I think you will take it for granted that the building generally tells you the purpose for which it was erected, if you are familiar with its style, and we all agree that a work should express this common-sense requirement. But often in modern times we find that this is ignored. In the Gothic revival, a movement which has been so beneficial to us as a nation, it is not to be wondered at that enthusiasm carried many of its disciples beyond the region of common sense, and that blunders were made which we must deplore. In the rage to build everything Gothic, the world containing the relics of the past has been ransacked, and the treasures gleaned have often been misapplied. Let us take an ordinary dwelling house, for instance. It is not unusual to find the porch looking as if it had been brought from some village church, and though it fulfils its practical common sense purpose, it does not commend itself to common sense intelligence, which demands fitness and expression of the use for which the work is intended. Neither are we impressed, on entering a small hall or dining-room, to find a chimney corner recess large enough for a spacious apartment, and there appropriate enough, but out of scale altogether where spaciousness could not be obtained. Common sense seems to demand that the fireplace should be proportioned to the scale of the room. Attempts, too, have often been made to plan houses on mediæval lines, ignoring the fact that the world has grown older and more civilized, demands refinement of plan and has introduced requirements which can only be met as they arise. Instances might be found where the dining room has been so placed that it had to be traversed by any person requiring access to the stairs or kitchen, and this not from want of skill, but from a desire on the part of the architect to reproduce the simplicity of living as it existed in the past. As well may we try to persuade people to go back to the inconvenience of the old stage coach and the slow delivery of letters. Yet many of you must know that attempts almost as unreasonable and deficient in common sense have been made by many men who, instead of seizing the spirit of the past, and designing in it, seek to reproduce the letter, and are imitators only. Again, we sometimes see a church-like gable and traceried window engrafted upon a house in the part occupied by the staircase, and looking more like a private chapel. The whole does not express its purpose. Both gable and window were right where they originally came from, but, transplanted, the incongruity is apparent to intelligent criticism. The butler carrying the dinner up this staircase in monk's garb would be thought quite out of place, and yet, would it be much more incongruous?

Church restoration and building both offer much food for reflection, as the most prominent result of the revival. The difficulty of building houses successfully in the Gothic style has always forced itself upon the attention of the designer. Our mode of living is so out of joint with it that it promises soon to go out of fashion for domestic purposes; but for ecclesiastical buildings it will probably survive, though even here there are signs of reaction. Now, as to restoration. The use to which our churches are put will vary according to the requirements of those who use them. Our days witness a return, in a large party of the Church, to more ceremonial observance. Previous generations had in their day ignored ceremonial, and at the Reformation had cleared the churches of all that, to their minds and teaching, symbolized the faith of their fathers. With the enthusiasm of the time a clean sweep was made of everything that served to recall the hated doctrines, and, from their point of view, it was a common-sense proceeding. These things represented, to their eyes, error and false teaching. Away with them. We know what followed. Whitewash, ceilings plastered up, churchwarden additions, pews, galleries, three-deckers. Then came the revival in church principles, and the demand for buildings which should act their part in teaching these, and men set themselves busily to work to restore and build churches to this end, and the example has been followed even by those who still adhered more strictly to the spirit of the Reformation. The religious aspect of this question is obviously only touched upon here to illustrate the reason for this change. If, as we have seen, the Reformers looked upon the building and its furniture as of no importance in teaching doctrines, the revivers of ceremonial in our day insist upon the building and furniture fulfilling this purpose, and so making use of the senses by external teaching. This being so, it is obvious that our churches, as they were some half century ago, were a standing protest to the new school of divines. They demanded that, for the proper and reverent conducting of the services, all those fittings and additions which we know as "church warden" should in their turn be swept away. As men's attention was called to our churches, the beauty of them became a popular study, and we all know how the enthusiasm spread, and what it has produced. This revival in the Church demanded, as we see, a return to the teaching of art as part of its system, and though its advocates do not insist upon it as a necessity of their creed, they welcome its use, as soldiers do the colors under which they serve. From this point of view, I think it may be granted as a perfectly common-sense way of effecting their end.

From the zeal with which the restoration of our old buildings has been carried on, much irreparable mischief has resulted. It is a natural consequence that it was so; for experience must be bought. What we have to look to is to buy it at the lowest rate possible. Seized with alarm at the blunders that have been made, many have rushed to the opposite extreme, and would stay the hand of the restorer altogether. These worthy people, actuated by honest motives, would leave the buildings as they are, or only do what was absolutely necessary to prevent their decay, by keeping out wind and weather. As archæologists and students, it is impossible to withhold sympathy from such intentions. With what delight do we enter a church where we find the whitewash and grey hairs of age! Here there is no mistake likely to arise as to what was part of the original building and what is churchwarden. You would probably after a little study of it be prepared with a scheme for restoring the fabric; but you doubtless will miss a great deal of pleasure if, on paying a visit to it at another time, you find your old friend with its hair dyed, and made young again, by some other restorer. But suppose the anti-restoration men had their own way. Decay we know is the mortal inheritance of all earthly things, and does not common-sense experience teach us that there is a limit to patching and propping; that circumstances often arise, over which we have no control, which necessitates radical alterations; that our buildings are from time to time put to new uses to which we must bend them or else leave them to decay? Leave them, say some; build others for what you need, but touch not with altering hand these stone books of the past. But, says common sense, these buildings were

erected for the purposes of worship, and men in previous years adapted them to their needs. This dedication to their high purpose is the most important, and therefore, as long as they afford shelter and can be made use of, men will avail themselves of them. Your interest in them is altogether secondary to this. Is it not impossible to lay down definite rules of what shall and shall not be done? Common sense must be used, and, further, we may say that, in dealing with such treasures as are bequeathed to us, only those well skilled in the work to be restored should be employed; and it is a pity that we have not some central authority to restrain such work from falling into the hands of men who, from want of sympathy with and ignorance of what they undertake, do an amount of mischief which is beyond recall.

In the building of new churches, common-sense requirements are too frequently overlooked. Here, as in other things, men forget that the world has moved on since the time that it produced the works that we admire, and that the more artificial life we lead now requires that more attention should be paid to the comfort of the people who are compelled to worship in cold and draughty churches. Because great simplicity in all such matters is found in the old churches, that, surely, is no sound argument for not seeking improvement in new ones. Now it is only common sense to know that, if you have a door opening direct into a building, and the weather is cold, the chilled air will enter by it, and make those people miserable who are in contact with the draught occasioned. Architects seldom dream of doing this in any other building where people assemble. We all know that in a house, where the money to be spent will allow, screen-doors are put to a hall, and in most cases some sort of a passage cuts off access from an external door and a room door. Why, then, should a congregation be exposed to danger,—for real danger it often proves to be,—by omitting so simple an expedient as a lobby of some kind? Contrast the comfort of a church or chapel where this is done with one unprotected from the blast.

Another serious omission is the absense of any mechanical and simple contrivance for admitting fresh air from outside, and warming it before it enters the building; for in winter, and the one we are having now calls our attention to the fact, it is misery to sit in a building with the windows open; so a close and stuffy atmosphere has to be breathed, no means existing to get rid of it and to supply fresh air in its place.

Other great causes there are which militate against warming our churches, —the large amount of glass, and the open roofs, both great chilling surfaces. Moreover, sometimes the boarding to the roof is not tongued, so that the hot air finds a ready escape, and so the heating apparatus is comparatively useless.

Common sense in planning is often sacrificed to supposed architectural effect, and as seeing and hearing are the most important points to be met for the com fort of a congregation, although where the means at disposal are limited, some sacrifices to effect may readily be granted; yet where this is not the case it is assuredly foolish to so seat the congregation that their view and light are interfered with by facing walls and other obstructions. These are difficulties that arise, and to ignore them for the sake of carrying out some likeness to what we have seen elsewhere, and for which, probably, sound reasons might be advanced, is a confession of weakness, and to this error may be attributed much of the lifeless work we have in our midst.

What a perfect medley do some designs present: here part of a monastery, there of a church; details reduced so in size from the originals from which they were taken as to look starved and wretch ed; chimneys overtopped by high roofs that will be sure to make them smoke; buttresses to resist no thrust; windows stuck in for appearance, coming anyhow to the rooms, now close to the floor, now above looking-out level; roofs that must from their construction thrust out the walls; passages ill-lighted, and tortuous in their windings,—these and other mistakes arise from ignoring the common-sense requirements of the purposes for which the building is intended, and with the mistaken idea of producing architectural effects by trusting to appearances only. Careful consideration of the plan, and working out of heights and sections of the construction, would have shown the designer his mistakes; and a more in-

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telligent studying of the works which fill his sketch book, that what looks well and suitable in a position for which skill has designed it, may become ludicrous if placed in a position which is foreign to its original purpose.

I cannot leave this part of my subject without a brief allusion to the style which has somewhat quenched our Gothic ardor, and which, for want of a better name, is called "Queen Anne." I believe I am right in saying that its sponsors promised in its name essenti ally common-sense qualities, and that it would more readily adapt itself for house architecture and modern wants. In my own opinion, I think there is much in it to commend itself as a style, but it is possibly only the prelude to a revival of Classic architecture. Here, as in the Gothic revival, men are and will be found hunting up old examples, and trying to make new houses look as much like old ones as possible; and as long as imitations are the fashion no real progress can be made. Touching Queen Anne, common sense may ask, why is it necessary to return to small panes of glass, and thick bars which obstruct the view, when you can get larger? Would the old builders have put them if they had not been obliged? Why is it that porches are built, and cut off short of the cornice, looking as if you had not bricks to finish with? To get light into the hall? But surely you can do this without resorting to so foolish an expedient. And why, in this dirty London climate of ours, do you paint your outside doors white or pale dull greens? After the first week's use they are dirty and disagreeable to look at. And while on the subject of painting, a great deal has been said against graining and varnishing; it is decried as a sham. But if you will soothe your conscience by calling it a conventional mode of decorating doors, &c., you will have a most useful agent. Beyond all question, for ordinary purposes, there is nothing that on the whole wears better, looks better, and goes better with the ordinary furniture and belongings of a house—a thoroughly common-sense method. But, to resume, why is it necessary to stick up tablets on blank walls, in all manner of positions, looking as if they had been bought up from a church under restoration, and set up here as a protest against the v[illegible]dalism that removed such precious works of art? Why, too, we may ask, is it necessary to be putting balconies, balusters, and railings where they are not wanted at all? And other questions of this kind will be forced upon you, if you will take a walk in the neighborhood of the Thames Embankment or Pont-street, and study the designs which are weekly supplied to us.

Much of the charm of the red brick style consists in its color, and there is no doubt that it has great capabilities when used with skill and sobriety. Too much of what we see is rendered feeble by the fussiness displayed and the ignorance shown in the mouldings, which are too often of a nondescript form.

I will, in conclusion, make a few remarks upon some of the causes which conduce to failure and violations of common sense, hoping to fulfill the object of this paper by exciting discussion upon it. I believe that the main cause lies at the root of professional training. Lads are articled to an architect, and left in the office, too often, to shift for themselves. You all know the usual course, so I need not stop to describe that; but I would urge the importance of reform,—that it should be an understood thing in the articles of agreement that a pupil should spend a large part of his time upon works in progress, that he might see for himself what drawings mean when carried out, learn the different modes of construction,—from foundations to painting,—be compelled to make measured drawings from the work, accurately showing how the parts are put together, and to make himself familiar with the terms and methods used in building. Better still, that after his pupilage was up he should, if it can be managed, be sent for a couple of years or so to a large builder, and there taught the practical side entirely of the question, even to manual labor, and that perplexing study, a builder's account. Engineers do this, and their works are pre-eminent for common-sense. Why should not architects make themselves also familiar with the capabilities of the materials in which they will have to work? The knowledge thus gained, combined with the experience of the office, and careful and systematic studies from old examples, would pro

duce men skilled, theoretically and practically, in their profession; and to those within reach, the Architectural Association offers immense advantages.

That we, as a profession, should hit upon some feasible plan by which competitions might be conducted on a fair footing, is much to be desired, and I trust that when the subject comes up here for discussion, some remedy will be found. If the Institute and yourselves were to combine to resist the injustices of the system, much might be done to discredit it. One thing we may assume as certain. The competition system exists, and is more or less popular. What is asked for is fairness from projectors and among competitors themselves. The appointment of a skilled professional man as referee seems a necessity, for this very common-sense reason,—no layman is competent to decide upon designs, and discriminate between rival merits. If competitors knew that designs must undergo the scrutiny of plan, sections, and details, those crucial tests of a man's practical knowledge, better designs would be sent in, and the simply draughtsmen-architects would be nowhere. Too much stress has, I believe, of late years been laid upon this quality of draughtsmanship and sketching. Excellent as accomplishments, they are not the be-all and end-all here.

USELESS BOILER SURFACE.

From "The Engineer."

More or less intimately connected with every apparatus intended for the generation of steam will be found a certain protion of surface which is of no direct use. This surface costs money in the form of capital to begin with, and may require for its maintenance in good order a further expenditure from time to time. A further objection to it is that it always represents weight, and it is consequently under certain circumstances very desirable that it should not exist. The difference between a good and a bad boiler not unfrequently lies wholly in the amount of useless surface possessed by the latter. Not quite so much importance has been attached to the subject as it deserves. If it were more considered, fresh departures in boiler engineering would probably be made with advantage.

Useless surface may be defined as that which adds nothing to the steam generating power of a boiler, and answers no other purpose in the best possible way. For example, the sides of the brick flue in which stationary boilers are set are useless for the generation of steam. The whole of the lower portion of the cylindrical flues of Cornish and Lancashire boilers, and the bottoms of the furnaces of marine boilers contribute nothing to the production of steam. It may of course be said that by using cylindrical flues we get a very safe and convenient form of boiler. If it can be shown, however, that quite as safe, and in other respects as good boilers can be made of a different form, then there is no reason why we should continue to make boilers in which there is useless surface. Within the last few years this truth has begun to be felt, although not expressed in quite the same way we speak of it. For exampie something has been done to utilize, the otherwise useless bottoms of Cornish boiler flues, by making them receive the lower ends of Galloway tubes. Again, the locomotive type of boiler, in which there is comparatively little useless surface, is growing in favor as a stationary steam generator. The same class of boiler is even beginning to find its way on board ship, and arrangements are being adopted now more than ever to render the otherwise useless surface of Lancashire boilers of effect. In these boilers the flame rushes straight to the back of the furnace and over the bridge, and some two feet or three feet in length of the front of the furnace crown is only of the least possible use as a steam generator. Experiments made to test this have been conclusive. By turning a brick arch inside the furnace some three feet long, measured from the fire-door, the steaming powers of boilers have been increased rather than diminished. Any expedient which will delay the flame in the furnace is of use, provided it does not interfere with the draught; and it is

for this reason, no doubt, that a furnace which we illustrated last week has so far and experimentally given such good results. We may consider the whole question from another point of view. For example, if a flue or flues are longer than is necessary, then the extra length is useless; and this will be found to admit of some very important deductions.

If we take the case of a Lancashire boiler, with flues of any given length—say 30 feet—it will be seen on reflection that the first particles of heated gas which come in contact with the iron of the boiler beyond the bridge, part with their heat and become useless; but instead of being got rid of there and then, they are carried further mixed with other volumes of gas, which they tend to cool down. Thus at each foot of length of the flue there are no doubt to be found volumes of gas which have fallen, perhaps, from 2000° to 400°, and which are reheated to 1000°, and finally leave the boiler at 700° or 800°. Along the centre of the flue may proceed a column of gas which never comes into contact with the plates at all, unless some device be introduced, such as brick bridges or Galloway tubes, to break it up. In locomotive boilers, again, small as the tubes are by comparison, there can be no doubt that the products of combustion are discharged at a higher temperature than they need be, because molecules of gas which have already parted with their heat are mixed with hotter gas, and although they cool it down, the resulting mixture is discharged at a hotter temperature than each group of molecules which had actually touched the brass of the flue. The extension of surface required to carry away degraded products of combustion, as we may term them, with those not degraded may be regarded as more or less useless. To make our meaning clear, let us suppose that from a sewage carrier, branches diverged, in each of which was placed a filter. Then as the sewage flowed down the carrier a portion would turn off to a filter, become perfectly purified, and then return again to the sewage carrier lower down, when it would of course become again polluted, and unless it could be shown that the whole of the sewage passed through a filter, it is clear that at the last no absolutely pure water would be delivered into the river which ultimately received it, and this although portions of the sewage might have been clarified several times over. It is obvious that such a system is bad, and yet it is precisely analogous to that on which boilers are constructed. The proper principle contemplates the rapid cooling down of the products of combustion, and no subsequent reheating. This end could be secured in a boiler in which the tubes were extremely small, say only ½-inch in diameter; such a tube will have a cross section but one-sixteenth of a 2-inch tube, while its surface will be four times less. Consequently a tube of the small diameter and two feet long would be as efficient as a 2-inch tube eight feet long. The latter would, it is true, have a surface of in round numbers four square feet, while the other, the ½-inch tube, would have a surface of about one-fourth of a square foot. But the small tube would deliver the products of combustion which passed through it, cooler than would the 2-inch tube, and for this reason much less surface disposed in the shape of ½-inch tubes would suffice than would be required were 2-inch tubes to be retained. The practical advantages which might be gained in many instances by the use of excessively small tubes will be apparent without further explanation. By saving what is now useless surface, and retaining only surface eminently useful, the weight of a boiler would be much reduced, and its cost would not be seriously augmented.

In order that all boiler surface may be rendered as useful as possible it is essential that the escaping products of combustion should be split up into the thinnest possible filaments. Only those who have tried it can realize the promptitude with which furnace gases thus treated part with their heat to the water in a boiler. There are certain objections, however, to the use of very small tubes on the score of first cost, small calorimeter, &c., which hinder their employment. But these cannot be urged against the use of sheet flues—that is to say, flues taking the place of tubes. These, if made not more than one-half inch wide inside and but one foot long, will as effectually cool down a heated gas as the ten-foot two-inch tube of a locomotive. That such flues can be employed there is no room to doubt. Messrs. Day

and Summers, of Southampton, used for many years with great success sheet flues less than two inches wide and about seven feet long by four feet deep. The introduction of high pressure stopped the extension of the system. We have no hesitation in saying that if any boiler engineer will take up the sheet-flue system where Messrs. Day and Summers left off, and push it to its legitimate end, a new class of steam generators can be produced which will be smaller, lighter, more powerful, and more economical than any that have gone before. There will be no useless surface about them. Only those who have seen a run of two feet or even less for hot gases, doing as much to cool them down as 100 feet of run in the case of a Lancashire boiler, or 10 feet run in a locomotive, will understand of what the further extension of the system of cutting up flame and gas currents into filaments is capable. It may be supposed that narrow spaces would quickly soot up. With a sharp draught—and all boilers on the system to which we allude must have a sharp draught—no sooting up will take place if good steam coal be used. For bituminous coals they are not suitable. We may add that so far as we are aware no patent stands in the way, and that it is open to any one who pleases to adopt the sheet flue system; and it is worth notice that vertical surface in these flues is just as good to all intents and purposes as horizontal surface. If an attempt be made to work with sheet flues more than half an inch wide inside disappointment will result. The essence of success lies in cutting the products of combustion into exceedingly thin slices, a layer of metal and a layer of gas turn about.

LIGHTNING CONDUCTORS.

From the "English Mechanic and World of Science."

THERE are many points upon which electricians do not agree among themselves, but perhaps no branch of their study has been the cause of so many conflicting opinions as lightning-conductors. If you find two electricians who agree as to the theory of the lightning-conductor, they will in all probability differ completely as to the manner of its application and the dimensions most suitable for a given purpose. The bibliography of the subject is extensive, and includes a number of papers from the most distinguished physicists of the present and the last century; but we doubt whether any practical information of much value is to be obtained by a perusal of the whole library, while the reader would certainly acquire a very confused notion of the subject unless he had already received a preliminary training in the principles. The author of the work before us seems to have felt the need of just such a book as he has produced, and his practical experience in planning out lightning-conductors has enabled him to produce a really useful guide to architects, clergymen, municipal officers, and others, upon whom may devolve the duty of protecting public and other buildings from injury by lightning. Mr. Anderson has not given us any pet hypothesis of his own as to the nature of lightning, but has judiciously consulted the works of the best authorities, and has furnished us with a readable history of the lightning-conductor, and probably a correct description of the nature of the effects it is intended to prevent. The practical part of the work is, however, the more valueable portion, as it supplies non-technical readers with information that many have desired to obtain. It commences with Chapter V., on Metals as Conductors of Electricity, in which the author has, rather uncharitably, exposed the liability of the most distinguished scientists to make serious errors. The relative conductivity of metals is known now-a-days with tolerable accuracy; but the figures given by such as Humphrey Davy, Becquerel, Ohm, Lenz, and Pouillet, are in some cases inexplicable. Davy taking copper as a standard at 100, found the conducting power of silver to be 109, and iron 14.6, while Becquerel, adopting the same standard, put silver at 73.5 and iron at 15.8, the comparative similarity in the one case making the discrepancy

in the other all the more remarkable. The figures given by Lenz are, however, more noticeable still, for he found silver to have a conducting power of 136 and iron of 17.7, while as if to render the subject more mystifying still, Ohm rated silver at 35.6 and iron at 17.4. Pouillet's figures are: silver 81.3, iron between 15 and 18. It will be seen that while the five distinguished experimenters gave very varying results for silver, as indeed they did also for gold, the figures apportioned to iron agree in a very remarkable manner, and there can be no doubt that by taking iron at 16½ and copper at 100, we have a probably accurate estimate of the relative conductivity of the two metals best adapted for making lightning-conductors. In the chapter on the Character of Lightning and Thunderstorms, allusion is made to the statement that Solomon overlaid the Temple within and without with pure gold, and thus, unwittingly perhaps, took the best possible means of preserving the edifice from injury by lightning. According to Josephus, Solomon ordered the whole roof to be ornamented with sharply-pointed and thickly-gilded lancets of iron, presumably to prevent birds settling there and soiling the roof. That these points played an important part in protecting the building there can be little doubt, for all experience has indicated the use of points and large surfaces of metal in the attempt to protect buildings from lightning. The chapter on Inquiries into Lightning Protection is a useful, though necessarily brief, account of experiments and reports hitherto made with the view of obtaining some definite data upon which to work, and that it is followed by a chapter recounting the experiments of Sir W. S. Harris. It is not impossible that more has been learnt from the failures of conductors than from a study of the theory of lightning, and there can be little doubt that copper is, all things considered, the best material for conductors. The remarkable discrepancies in the conductive power of metals alluded to above were, in all probability, mainly due to the use of impure samples, for Prof. Matthiessen found that if pure copper were taken as standard 100, best American would be only 92.5; Australian, 88.8; Russian, 59.3; and Spanish Rio Tinto only 14.24. Objections were formerly urged against copper on account of its expense; but a more potent reason for its neglect was the simple fact that a suitable copper conductor could not have been obtained. It is essential that the copper should be as pure as possible, for as it is six or seven times the price of iron, it is advisable to take full advantage of the greater conductive power of the more costly metal, which it will be seen nearly balances the difference in price. So far it may be said that iron and copper are practically equal, but there are two other points to consider, and in both of these copper is by a very long way the superior of iron, viz: durability and flexibility. We can readily agree with Mr. Anderson, then, that copper is the best material for a lightning conductor, and it is not impossible that the wire ropes made by Newall & Co., which have, we believe, a guaran teed conductivity of 93 per cent. of pure copper, are the most suitable things in the market. Chapter X. describes what has been done at the Hotel de Ville, Brussels, and at Westminster Palace, the former building being probably the best protected of any in the world. It is covered on a plan devised by Professor Melsens, consisting of a perfect net-work of metal, with numerous points and ample and perfect earth-contacts. The descriptions of the measures taken to protect these buildings will serve to show what is considered good practice, and the practical details under the head of weathercocks, and descriptive of practice in France and America, will help to make the subject clear. The chapter devoted to an explanation of Newall's system is, however, an epitome of the whole subject, and as numerous examples are given, the reader perceives clearly what is required for a barn, a house, a factory chimney or a church steeple. The system advocated by Melsens, of many small rods, instead of one large one as adopted by Mr. Anderson, but it is tolerably well understood now-a-days that advantage should be taken of the presence of any considerable piece of metal in a building to bring it into the circuit of the conductor. Thus a church, for instance, instead of ridge tiles should preferably have a ridge of iron, which could be connected to the conductor, and so save the expense of running a

copper rope from end to end. Several illustrations of the arrangement best adapted to special cases are given by the author, who also gives particulars of such minor details as fastenings, which should preferably be copper clamps built into the wall, in the case of a chimney for instance, though simple staples nailed to the wall will do very well in the case of the smaller and lighter conductors employed on houses. Not the least interesting portion of the book are the illustrations of the effects of lightning as seen in the case of churches and other buildings that have been injured by lightning, an engraving of the monument to General Baird, on the summit of Tomachaistle, near Crieff, serving as a frontispiece, and an excellent example of the disruptive power of a lightning stroke. The "earth connection," very appropriately, has a whole chapter to its consideration, and there are several engravings showing the most approved methods of insuring that at all times the earth wires shall be capable of distributing the discharge. A chapter urging the necessity for frequent inspection and testing of all lightning-conductors, brings the work to a close—a very full bibliography forming an appropriate appendix. The book is well printed on good paper, and will, no doubt, become the standard text-book for use by those who are engaged in erecting lightning-conductors,

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MANUFACTURE AND MELTING OF IRON AND STEEL.—In the ordinary method of manufacturing iron the blast-furnace in which the iron ore is reduced is urged by a blast of atmospheric air. A blast of atmospheric air is also employed in the treating of iron by the Bessemer process for the production of steel, as well as in cupolas and refineries in which iron is melted for casting and for refining. The blast employed is drawn direct from the atmosphere, and contains a greater or less amount of the vapor of water varying with the hygrometrical condition of the atmosphere from time to time. This vapor of water undergoes decomposition in the furnace, causing an absorption and loss of heat therein, varying from time to time in proportion to the greater or less amount of vapor thus introduced into the blast. The hydrogen evolved by the decomposition referred to gives a porosity to the iron or steel under treatment, which is very injurious in castings.

In order to prevent the loss of heat referred to, and thus to economize the fuel employed, and promote rapidity of fusion and a regular working of the furnace, and also to prevent to a greater or less extent the porosity produced in the iron or steel made or melted with air containing vapor of water, Mr. W. H. Fryer, M. E., of Coleford, Forest of Dean, proposes the desiccation of the blast. He passes the air to be forced into the furnace, cupola, or refinery, or Bessemer convertor, through or over sulphuric acid, or chloride of calcium, or other desiccating material, so as to deprive the said air wholly or in great part of the vapor of water contained in it. The desiccating material may be disposed in various ways in a chamber or receptacle through which the air is passed, the particular arrangement depending upon the nature of the material employed (whether solid or liquid) and its desiccating and other properties, the essential conditions of the arrangement of the said material and chamber or receptacle being that the desiccating material shall expose a larger surface to the air, and that the capacity of the chamber or receptacle shall be such that the air will travel through it at a sufficiently slow rate to ensure the thorough action of the desiccating material upon it. The desiccating material may be either supplied continuously or renewed from time to time as occasion requires, the particular arrangement for supplying and renewing the same depending upon the nature of the material (whether solid or liquid) and its desiccating and other properties, and the mode of restoring its efficiency when lost by use. Although the invention is principally applicable to furnaces used in the manufacture of iron and steel, and through which air is urged by a blast, yet it may also be applied to furnaces through which the current of air for maintaining combustion is drawn by an exhaustion, whether the said exhaustion be produced by a steam or other motive power engine, or by the draught of the heated and rarefied air in the chimney stack.—*Mining Journal.*

THE PATENT LAWS AND THE PATENT OFFICE.

By JAMES A. WHITNEY, Counselor-at-Law.

Contributed to VAN NOSTRAND'S ENGINEERING MAGAZINE.

THE promotion of industries is the source of national wealth. The prosperity of all modern nations is due to a recognition of this truism. And among all the means for insuring the development of useful arts and the extension of commerce, there are none that have been more efficient than the system of protecting inventors, during limited periods, in the enjoyment of the fruits of their intellectual work. The reason of this is manifest. If the result of a given amount of labor on the part of an individual be multiplied ten-fold, the value of that individual to the community is increased in a like ratio. The same result is obtained as concerns communities, for if a city, state or nation, is enabled to multiply the results of its labor, in proportion to the number of its population, its importance in the great family of nations is proportionately greater. And if we extend the principle to embrace the various countries of the world, we find the result to be simply this, that the capacity for production being extended, the supply, to meet the wants of humanity, is correspondingly promoted. Hence it is that the comforts of life at the present time are far greater, and far more easily obtained for all classes and grades of society than they were two hundred and fifty years ago. We have only to adopt Macaulay's comparison of the condition of the English people in the time of Elizabeth with that of the time in which he wrote, a third of a century since, to perceive to what an extent the adoption of inventions—or as they are technically termed improvements in the useful arts—have ameliorated the condition of the human race. It is true that the development of industries cannot be traced to any single source; and it is true also that natural causes as well as legislation have contributed directly or indirectly to the results just indicated; but it is equally true that no single agency has equaled in efficiency, or in the magnitude of its fruits, the system of granting letters patent for inventions as an incentive to the production and application to use of practical improvements.

As relates to the history of the system, its inception can scarcely be traced. Something of the kind, as we are told by Montesquieu, held an important place among the land laws of the ancient Persians, and conduced in no small degree to the reclamation of the sandy wastes between the Euphrates and the Tigris. Something similar in principle existed among the Romans in the usage, which protected orators against the illicit reproduction of their manuscripts. In Europe, as concerns industrial arts, the first instance of which we have knowledge was in the latter part of the fifteenth century, and related to the new practice of an old art, that of manufacturing saltpetre, rather than to the practice of a new invention.

Patents were granted in Nuremberg during the period of the Renaissance, and in England for the first time in the reign of Edward III., and curiously enough for the production of the Philosophers' stone, the possibility of the transmutation of metals being then a matter of universal belief. The first fruits of the system, however, appeared on the continent, and through the encouragements thus given, the manufacturers of Flanders, France, and some parts of Germany reached a high state of excellence in their work and products, which latter found a ready market in England. From this arose what may be termed the inception of the middle classes of Great Britain, a mercantile and trading class as distinguished from the warlike barons on one hand, and their servitors on the other. It was this class that really turned the scale in the wars of the Roses in favor of Edward IV, for had it not been for the support of the trading community, the defeat on Barnet-field, of Warwick the king-maker, at whose tables thirty thousand fighting men are said to have sat at meat, would have been impossible. The protection of industries on the continent, therefore, led to the full development of the commercial spirit

in England, and this, in its turn, produced a condition of society favorable to the next advance, that of the permanent planting of manufactures on British soil, whence, after long lapse of time, they extended to our own country. It was during the period between the reign of Edward IV and that of James I, that the protection of new inventions by letters patent grew up side by side with a quite different one, the mischievous system of monopolies, which, although of quite opposite character, has often been confused with patents granted for meritorious inventions. The difference, however, is plain, when we consider that an invention is something new, something that the public has never possessed before, something that is an addition to the previously existing property and knowledge in the world; whereas a monopoly in its widest sense is something taken from the public, and given over to the benefit of the few. New inventions, by adding to the resources of labor increase wealth, and promote comfort, while monopolies in articles previously in general use, by restricting the exercise of known arts, are full of harm to all except the monopolists themselves.

During the period last referred to the tares grew quicker and higher than the wheat; so that the protection of new inventions was overshadowed by the creation of monopolies which at last grew to be a bitter grievance and a hindrance to the national growth. It was this which produced the great revolution, and in the famous statute of monopolies in the 21st year of James I, A. D. 1623, the line was distinctly drawn between meritorious letters patent, which are advantageous to the growth of industries, and the harmful exclusion of the public from the practice of trades, occupations, or branches of business, that are part of the common inheritance of the people. This celebrated statute forbade monopolies, but expressly permitted the granting of letters patent: for any new manufacture within the realm was specifically excepted, and left unharmed. It is to this period that the text writers refer the origin of patent laws, but as a matter of fact this statute created no new protection for inventors, for as concerned *bona fide* inventors it left the matter as it had been from an unknown date in the administration of English law, and no material change was made for more than two hundred years, except in so far as the courts construed and elaborated the meaning of the terms employed in the statute of monopolies.

Our own country derived the system from England, each colonial government having the right to issue patents within its own jurisdiction in the same manner as they were issued in England, although the English government in some cases, issued patents that included both England and the colonies. After the establishment of our independence, the states continued to exercise this power within their own borders, and it was in this way that the State of Maryland accorded to James Rumsey, the exclusive privilege of making and selling "newly invented boats of a model by him invented," in the year 1785; and Fulton owed his financial success to a similar patent granted by the State of New York. In the year 1790, Congress passed a general patent law, the effect of which was to transfer the administration of the system entirely to the General Government, it being provided that no patent should issue under the act, on any invention which was the subject of a patent from any state. This, therefore, was the beginning of the present or Federal patent system of the United States. But the administration of the system has been from the first modeled upon the practice and precedents laid down by the English courts before the date last mentioned. British decisions during the latter part of the eighteenth century, and notably the *causês celèbre* of the *King* vs. *Arkwright*; *Watt* vs. *Hornblower*, and several others, elaborated the ethics and applications of the law, into a complete and rounded system. It is to Judge Story, who followed closely the precedents of English jurists, that the credit belongs of molding the American law of patents into consistency and shape.

The patent law proceeds primarily upon the fact, that improvements which increase the result of human labor or multiply the fruits of industry are advantageous to civilization, and beneficial to the community at large. It, therefore, becomes necessary to offer a premium to genius and skill for the production of the desired improvements. And of all

methods that have been attempted, experience has decided that there are none so simple, so manifestly equitable, and so convenient in actual practice as that of permitting the inventor to appropriate to himself the profits of the invention, during a certain limited time, upon the express condition that he disclose his improvement to the public in such shape and in such a manner, that after his peiod of exclusive use has expired, the public will be enabled to put it in operation. This is the principle of the law of patents, and it rests upon the same ethical ideas as the law of contracts. The exclusive privilege is given in payment for an invention to be dedicated to the public at the end of a certain specified time. All that the inventor can gain from it during that time is his, while to the public belongs all that the public can gain from it in all the ages after. But while this is the principle of the law, and its result as well, there is still another advantage to the public in the fact that the placing of a new improvement in the market, or adding a new invention to the resources of any branch of industry, even while under the absolute control of the inventor, is itself an immediate gain to the community, for the manifest reason that the community will not adopt the improvement or enable it to afford profit to the patenee, unless it can itself gain by so doing.

The principle of the law being thus stated, it is of interest to consider its administration. In order to provide for the granting of patents under suitable guarantees, or rather under suitable assurance of novelty and utility, the Government has organized a special bureau charged with the examination of every application, and the issue of every patent when its subject matter is found to be new and useful. This bureau, under the charge of the Commissioner of Patents, forms a part of the Interior Department, the Secretary of the Interior being invested with general jurisdiction over the Patent Office. There is, in addition to the Commissioner, an Assistant Commissioner and a Board of Examiners-in-Chief, comprising three judges, at the present time acute and experienced judicial officers whose decisions are frequently models of close and accurate reasoning, characterized by a clear appreciation of the true spirit and intent of the patent laws. The examining corps proper consists of principal Examiners together, with first, second and third assistant examiners. There is, in addition, a special Examiner of Interferences, and a large force, many of whom are ladies, devoted to the clerical work of the office. It will be seen that the organization is necessarily complex, and that its magnitude is considerable. The complexity would be obviated, and the work of the office would be much better performed, if the working force was increased, and excessive labor was not required from officials, who, as a rule, earnest, industrious, and efficient, have long been over-burdened and underpaid. In other words, a more numerous force, and better pay would render of easy attainment, an excellence of administration that is now impossible.

The several steps necessary to obtain a patent may be briefly stated as follows: There must, in general, be provided a model, which should be of substantial material. The invention must be represented by drawings where such are possible, and these should show the invention clearly and in detail, and must be of a character which will permit them to be photo-lithographed. A description of the invention, which, with the drawing, constitutes the specification must also be filed, and must contain a clear and condensed description of the improvement. It must also clearly state the parts or combinations that are claimed to be new, and as a rule must embody a brief statement of the previous state of the art to which the invention relates. It frequently happens that an invention is found to be anticipated in part, and in such cases an amendment, properly drawn to cover what is new and to exclude what is old, must be filed before the case can be passed to issue. Of course if the invention is found to be wholly anticipated by some anterior invention or by something so nearly like it that nothing more than mechanical judgment is required to make the old device equal to the new one, the application is rejected. On the filing of each application, a government fee of fifteen dollars is required to be paid, and an additional fee of twenty dollars before the patent is issued.

The time required to obtain a patent after the papers are filed, varies according to circumstances. If the application is properly prepared in the first instance, and the invention is not anticipated in any of its essentials, the allowance will depend simply upon the condition of work before the examiner to whom it passes for examination; and this may be from two weeks to two months. Some classes of invention are so complex that the examiners are necessarily behind with their work, so that the cases being taken up in their order of filing are always more or less delayed; while in others it is possible for the examiners to keep the work so closely in hand that but a few days are required between the filing of a case and its allowance. If, however, by reason of partial anticipation of the invention, or other causes, amendment is necessary, further delay is caused, and the progress towards issue in such instances depends upon the diligence of the applicant or his attorney, and upon the skill displayed in so framing his papers as to place the case accurately and clearly before the examiner. Sometimes where an interference is declared, the delay may be extended to several months, the time being required for the taking of testimony, the making of motions, and other proceedings necessary in arriving at a judicial decision on the merits.

Assuming the specification, drawings and model to have been properly prepared, and the petition, etc., to be in due form, the course of an application in the Patent Office is as follows: The model goes to the machinist, whose business it is to ascertain if it be of proper size and finish, and of substantial make. The specifications go to an official of long experience, who looks to the regularity of the papers, but without examination of the contents of the specification; while the drawings are sent to the draughtsman who examines them as to their size, legibility and fitness for lithographing. In the meantime, the fee of fifteen dollars is paid into the office of the chief clerk. The model, drawings and specification, together with the petition and affidavit attached, are then assembled and sent to the examiner to whose class the case belongs, and by him it is taken up for examination in its course. The preliminary work of examination is commonly done by an assistant examiner, each principal examiner being held responsible for the work done in his room. If an application is rejected, the applicant is entitled to a re-hearing before the principal examiner; if the latter persists in his rejection an appeal lies to the Board of Examiners-in-Chief. If the case be still rejected by this tribunal an appeal lies to the Commissioner in person, or in his absence to the Assistant Commissioner, as acting commissioner, or, when the applicant consents, before the Assistant Commissioner, in his capacity as such. If the case is still rejected and the applicant is satisfied that he yet has grounds for a further appeal, such may be taken to the Supreme Court of the District of Columbia. The government fees required by these appeals are ten dollars when the appeal is to the Examiners-in-Chief, twenty dollars when to the commissioner, and ten dollars when to the Supreme Court of the district. In cases where the patentability *per se* of the invention is admitted, but the invention is claimed by two or more different parties, an interference becomes necessary. The proceedings in such cases resemble those of an action in equity. Apart from special motions (which at certain stages may be made and tried before the principal examiner, the Examiner of Interferences or the Commissioner in person, according to the state of the case), the hearings are as follows: First, before the Examiner of Interferences; second, on appeal before the Board of Examiners-in-Chief, and third, on appeal to the Commissioner. In interference cases there is no direct appeal from the commissioner to the Supreme Court of the district as in *ex parte* applications, but a separate action in equity may be maintained even after a patent has been issued in accordance with the decision of the Patent Office.

It will be seen from the foregoing that the proper prosecution of cases before the Patent Office is a matter of some complexity, and involves no slight degree of professional judgment, skill and care, and that the duties of the Patent Office are onerous and responsible to the last degree. On this last mentioned point it may be justly said that more of the complaints that have been made against the

general efficiency of the Patent Office have arisen from misapprehension of the character of the duties required of the officials, and of the skilled professional labor necessarily called for in the preparation and prosecution of cases, than from any actual mal-administration within the Patent Office. While undoubtedly instances sometimes arise where individual examiners through carelessness, lack of experience, or native perversity of temper, work injustice or annoyance to an applicant; such are not common nor are they to be taken as fair examples. There is probably no department of the government where high acquirements and uniform courtesy are more imperatively demanded or more fully displayed than in the administration, and by the officials, of the United States Patent Office. And while, as I have said, occasional instances arise where complaint may be justly made, yet these are probably few as compared with cases where incompetent attorneys have been helped out of their difficulties by the courteous, though extra-official suggestions of examiners. This last, however, although in motive creditable to the examiners, is productive of evil by encouraging the slovenly preparation of applications, and by enabling persons comparatively incompetent to persist before the office in the *role* of attorneys. The result in such cases is to shift the duties of the attorney upon the examiner, who is employed and paid by the Government, not to prepare applications or amendments, but to act considerately and justly upon them after they have been duly filed.

In another respect, however, there is a just cause of complaint, not against the Patent Office, but against the parsimony of the Government, which keeps locked up in the treasury nearly a million of dollars drawn from the resources of the Patent Office, instead of devoting it to the enlargement of the latter and the increase of the means for the proper transaction of business. Since the re-organization of the Patent Office in 1836, salaries of officials in every other branch of the government have been materially increased, but in so far as concerns the Patent Office, they remain substantially the same. And this, too, notwithstanding the fact that the intricacy and multiplicity of the duties of the Patent Office is much greater now than then. The bureau is inordinately cramped for room. It is keeping within bounds to say that ordinarily six persons, examiners, copyists, etc., work in a room of a size not more than sufficient for the comfort and convenience of three. The exacting labor of some of the most important classes is carried on in apartments originally designed, it is said, for coal bunkers, and in which the moisture creeping through the walls brings discomfort, if not illness, to the occupants. This and many other drawbacks to the perfect working of the Patent Office could be remedied by wise legislation and a judicious use of money that should be devoted to the purpose. It is well, while waiting for the slow evolution of a public opinion which shall compel a just consideration of the deserts of this bureau, that the community at large should apprehend to what extent the Patent Office is compelled to make the best of very untoward circumstances. Speaking from my own observation, during years of professional practice before the department, I can truly say that I do not believe that any other body of men have performed duties equally onerous in a more conscientious manner, or for smaller remuneration both of money and popular appreciation, than have the officials of the United States Patent Office.

In coloring and lacquering brass work, browns of all shades are obtained by immersion in a solution of nitrate or the perchloride of iron, the strength of the solution determining the depth of the color. Violets are produced by dipping in a solution of chloride of antimony. Chocolate is obtained by burning on the surface of the brass moist red oxide of iron, and polished with a very small quantity of blacklead. Olive green results from making the surface black by means of a solution of iron and arsenic in muriatic acid, polished with a blacklead brush, and coating it, when warm, with a lacquer composed of one part lac varnish, four of tumeric, and one of gamboge.

THE STEAM ENGINE OF THE FUTURE.

By JOHN BOURNE, C. E.

In all human affairs an insight into the future can best be obtained from an intelligent review of the past. The lines along which improvement has advanced in former times will also be those through which it will flow in times to come, for the continuity of the grooves in which the motive forces act is not broken by the horizon of the Present, but, on the contrary, extends into the Future with the certainty of inexorable law. The direction of these hidden prolongations, moreover, can be approximately determined by observing the routes followed in that part of the course which, having been already completed, is clearly in sight, and the laws which govern the advance, and which act alike in the past and in the future, are thus rendered discoverable. It is from the aid rendered by this method of research that I am enabled to speak of the "Steam Engine of the Future" with warrantable confidence, as such future stands as plainly revealed to me as if it had already passed into the attestations of history.

It is now more than thirty years since my "Treatise on the Steam Engine" was published. Of course, before writing that work I had to study the subject, and many years of antecedent experience were given in its pages. I can therefore, I believe, without arrogance claim to have had as prolonged and as intimate an acquaintance with the steam engine in its various phases as any person now living; and if this be so I am entitled to speak with corresponding confidence of the present condition and future prospects of that great instrument of civilization. When I began to write the class of small engines, now applied to the operations of agriculture and to the multifarious uses of the arts, hardly existed at all; and the knowledge of the steam engine was confined to a narrow circle and was jealously guarded. I believe that I was mainly instrumental in throwing open the portals of this technical empyrean; and a little before the date of the first Exhibition small engineering factories, profiting by the information thus placed within their reach, began to spring up in considerable numbers. Blacksmiths and agricultural implement makers rapidly expanded into full-blown engineers; and in many cases the want of skill in their productions was little redeemed by fastidious modesty in their pretensions. At first the demand for small engines for miscellaneous purposes was not very great. But it has gone on increasing at an accelerated pace; and, notwithstanding their existing imperfections, small engines of different kinds are now produced to the extent of some hundreds of thousands yearly. The demand, too, it is quite clear, is still in its infancy, and will rapidly swell into more imposing dimensions than have yet been anticipated by even the most sanguine mind. There are various causes for this, which it will not be difficult to specify. In the first place, the natural increase due to the known acceleration in the rate of the demand will necessarily be large. But new and more extended fields of activity are fast opening up. Thus, in works and factories of every kind it is the impending tendency to split up the large central engine which has been heretofore in use into a number of small engines, placed in convenient situations about the works. A central engine, transmitting its motion to distant points by means of shafting, expends a large proportion of its power in friction; and if any portion of the engine or of its gearing should be accidentally disabled the whole establishment is brought to a stop. By substituting several small engines for one great one there is less waste of power from friction; shafting is saved; and should any accident happen to one of the small engines only a part of the works is stopped, and comparatively little inconvenience ensues. In all new factories several small engines instead of one large one is now accounted the preferable arrangement for supplying the motive-power, and even in existing factories the replacement of the great lethargic engine of the old type by several small high-speed engines has already begun. In this inevitable substitution there is a new source of demand for small engines, which, in the future will

rapidly become extensive, though in the past it has been but little felt.

Some years ago I was induced by a friend to become a director in an iron company which had large works in Wales. The machinery I found to be of antiquated pattern. There were two separate rolling works, in each of which there was a great central engine, driving rows of mills right and left for puddle-bars, for rails, plates, &c. The shafting was carried in a tunnel underground, and the motion was communicated from the engine to the shafting by an aggregation of toothed wheels, which also drove a great flywheel moving at a high velocity. I scarcely ever visited these works that I did not find some part of the machinery broken down. If the feed of the rolls were accidentally made too rapid, or the iron during the rolling became, from want of steam or otherwise, too cold, then, the motion of the rolls being resisted, while the great flywheel could not be suddenly arrested, the intermediate gear gave way, the whole of the mills were stopped, the half-puddled iron had to be withdrawn from the furnaces, and the men were thrown idle until a repair could be effected. On applying the indicator to the engine I found that there was not very much difference in the amount of power consumed, whether the mills were rolling iron or not, the larger part of the power being, in fact, wasted upon the friction of the shafting. I recommended that the shafting and gearing should be discarded, and that a separate small engine should be applied direct to every mill. This recommendation was adopted by the directors, but was objected to by the proprietors. The directors resigned, and successors, who had dissented from our policy in this matter, were appointed. But the penalty inseparable from a defiance of natural law soon followed. The works had to be discontinued, and the company was broken up.

Another considerable increase in the demand for small engines impends from the prevalence of the system of compounding. In cotton mills and other factories possessing old-fashioned engines, working with a low pressure of steam, it has for a number of years been a common practice, when new boilers were introduced, to make them capable of withstanding a higher pressure. A high-pressure cylinder was at the same time added to the old engine, and the steam was first used in the high-pressure cylinder, whence it was dismissed into the low-pressure cylinder in the manner of compound engines. By this arrangement the steam can be made to do double duty, and the power can be produced with half the coal. The system, however, as hitherto carried out is subject to several drawbacks. The application of another cylinder to the existing engine involves the stoppage of the works until the new cylinder and its gear can be fitted. The parts of the old engine are generally too weak to be capable of transmitting the increased strain without the risk of fracture, so that sundry new parts have to be substituted; and, as the piston of the new cylinder must move synchronously with the piston of the old, the motion is slow, and the new cylinder and its connections are consequently both large and costly. It has been pointed out by me that, instead of compounding, as it is called, in this clumsy fashion, the same end could be more easily and inexpensively attained by introducing a high-pressure high-speed engine into any convenient part of the mill or factory, and coupling this engine by means of a belt to any convenient shaft running at a high speed, the educted steam being led by a pipe to the old engine to work it. The new engine, as thus applied, might be quite small, and its introduction would not involve any stoppage of the works. There is no doubt that this is the method of compounding which will henceforth prevail, and a very considerable demand for small engines will spring up to enable the system of compounding to be thus applied.

Another new source of demand for small engines, more important probably than either of the foregoing, is opened by the introduction of the electric light. It appears now to be almost certain that electric lighting will, within a few years, supersede to a great extent the modes of lighting heretofore in use. The most economical source of the electricity required for this purpose is the steam engine; and, as the electricity cannot be conducted without serious loss through any considerable distance, it cannot be distributed like gas from a great central

works, but must be produced by small engines at a number of independent centres. This new field for the steam engine promises to become one of great extent. But, in common with the indications in the other cases mentioned, the additional power is required, not in the form of a moderate number of very large engines, but in the form of a very great number of small engines moving at a high speed. In considering the probable extent of the conquests to be achieved by the steam engine in the future it is necessary to have regard, not so much to the condition in which that great instrument now is, as to the condition to which, under the influence of causes already in operation, it may reasonably be expected to ascend. The small engines at present offered for sale are often very defective; they are heterogeneous in design, and reveal in many cases conspicuous mechanical incapacity, and are generally produced under circumstances which hinder the combination of excellence with cheapness. In the interest of the public the desideratum manifestly is to have the most perfect possible design settled by the most competent existing authority, and to have engines on that plan, and that only, manufactured by special tools, without hand labor, whereby the greatest accuracy of production is insured at the minimum of cost. The mechanician who made for the Government the first of the army rifles now in use informs me that its cost to him was £62. It was made with the aid of the tools usual in engineers' workshops; and another example made in one of the Government workshops cost about the same sum. With the aid of special tools, however, in a factory erected for the purpose, the same rifles are now made for *fifty shillings* each.

The arrangements which cheapen rifles will also cheapen steam engines. But before such arrangements can be carried out the engines must be made in quantity, on a uniform plan, from which no departure can be permitted, and the parts of each class of engine must be interchangeable. Small engines are now generally made of divers forms, with little skill, in limited numbers, at different small workshops scattered throughout the country, without the aid of those complete arrangements which are necessary for really cheap and accurate production. Even with such drawbacks, implying in most cases a low quality and a high price, the demand for these engines has rapidly increased. What, then, would the demand have been if all the desiderata known to be attainable had been utilized and combined?

But who is to prescribe the type of the small steam engine of the future? It is obvious to everyone that it is desirable, in the interest of the public, that the best type should be selected, and that *it* only should be made, for thus alone can the factory system be applied to the manufacture, and thus also can the public be most readily educated in the management of engines, as they are enabled to escape the perplexities incidental to heterogeneous forms. But how, it will be asked, is any general agreement to be arrived at as to the type of engine that is the best? To this the answer is, that the preponderance of opinion which has to determine this point must be informed and competent opinion, and that the light thrown on the future by the experience of the past gives an unerring clue to the solution of the problem. The limiting considerations on every side which will thus be made manifest will fix the main outlines of the design beyond the power of cavil to contest, and will guide public opinion to the selection of that type that will soon swallow up all the rest.

Thirty years ago I predicted that all rotative engines would become high-speed engines—a prediction which experience, so far as it has gone, has amply confirmed. There were difficulties, no doubt, in the way of this acceleration, but these were clearly superable, and the benefits resulting from the employment of a high speed were so numerous and momentous that it was easy to foresee that nothing could prevent the general introduction of the principle. I had a small engine constructed to ascertain the limit of speed which was feasible with engines of ordinary construction, and I found that when this small engine was run at a very high speed it shook the whole house, and the people in the neighbouring house sent in to ascertain what we were about, as the engine shook their house also. This tremor was obviously caused by the unbalanced momentum of the recipro-

cating parts of the engine, and the remedy for it was not difficult of perception. But about this time I was called to India in connexion with the introduction of the railway system into that country, and I had no opportunity of resuming the consideration of the subject till some years afterwards. On my return I constructed some screw vessels which were fitted with direct-acting engines, and which were intended to maintain a high speed. At that time screw vessels were generally fitted with gearing, by which the required velocity of rotation of the screw was maintained while the engines moved at the same slow rate which had hitherto been usual in engines of every kind. With the high speed of engine I employed it became necessary to balance the momentum of the reciprocating parts, which was done by applying counter-weights to the crank, so that when the piston and its connexions moved in one direction the counter-weights moved in the opposite direction, and thus took all shock off the shaft. This contrivance, which has since been very widely introduced in large engines of the best class, I patented, and its use is indispensable to enable steam engines to work smoothly at a high rate of speed.

In accordance with my anticipation, gearing in steam vessels is now completely discarded, and the engine is coupled immediately to the propeller. The benefits of this arrangement are too conspicuous to require much exposition. Not only is the noise and complication of the gearing avoided, but, as an engine with any given pressure of steam will generate a given amount of power at each stroke, whether the strokes per minute be many or few, it is clear that the amount of power generated by a given engine in a given time will be in the simple ratio of its velocity, and hence a given power may be generated with less first cost, with less weight of metal, and with less space occupied, by a fast engine than by a slow one. Of course the fast engine must be suitably constructed to be able to run with impunity at the high speed, to which end not only must the momentum be balanced, but the bearings must be of special metal and have a larger amount of surface than sufficed in the old slow engines. But these adaptations create no difficulty, and steam vessels with balanced high-speed engines, working day and night for weeks consecutively without any stoppage or difficulty, are now plying to all parts of the world. These engines are quite as durable as the old slow engines, and much more economical in fuel. It may be taken as an axiom in steam engineering that whatever is feasible at sea is certainly feasible on land, for the more difficult problem comprehends the more easy.

The benefit of working steam engines expansively is well known to engineers, as also the necessity of employing a steam jacket in engines so worked, to obtain the full benefit of the expansive principle. It is not generally known, but is nevertheless the fact, that in high-speed engines there is a further benefit arising from the inability of the cylinder to become sensibly heated and cooled at each stroke, from the shortness of the time given for that process, and in such engines the cylinder approaches to the condition of a non-conductor, which is known to be favorable to the economical generation of power. Then, in the case of all high-pressure engines, it is easy to see that a considerable pressure must be more beneficial than a lower pressure. To raise a given quantity of water into steam takes just the same quantity of heat, whether the evaporation is effected at the pressure of the atmosphere or at six or eight times that pressure. But at the low pressure the steam will not generate any power, whereas at the high pressure it will generate much power. A very high pressure of steam, however, is inconvenient, as it involves a correspondingly strong and heavy boiler, an extra strong and heavy engine, and separate expansion gear, which is not compensated by the small amount of increased economy obtained from excessive pressure. I have found a pressure of about eight atmospheres to be, on the whole, the most eligible that can be adopted.

I propose to limit this review to the case of small high-pressure land engines, and the principles which have been enunciated will indicate pretty clearly the main characteristics which must distinguish such engines in the future. First of all, they must be *high-speed* engines. Next, they must have the momentum of the reciprocating parts *balanced* by coun-

ter-weights. They must be supplied with steam of considerable pressure, worked expansively, and the cylinder must be steam-jacketed and lagged. They must obviously be both light and strong, compact in form, simple in construction, and with all the parts easily accessible; and they must also be self-contained, so that an engine may be lifted in a piece and be worked in either a horizontal position, on a separate pedestal, or placed vertically against a wall or the side of a vertical boiler, as circumstances may render advisable. Of course means of efficient lubrication must be provided. These several indications in 1870 I embodied in the design of an engine constructed for me at that time by Messrs. John Penn & Sons, and in settling the details of which I had the advantage of their assistance. This engine, of which detailed drawings appeared in my recent work on "Steam Air and Gas Engines," and which is represented in the annexed cut, is now employed in generating the electricity for the electric light at the Polytechnic Institution, in Regent street. But although this and other similar examples constituted a great advance upon pre-existing designs, these early engines were by no means free from faults, which have only been eliminated by degrees, and an improved type, divested of these faults, has thus been gradually evolved in the course of years. There is no such thing as finality in steam-engine improvement. But a stage of ascertained efficiency has now been reached which, I think, warrants production being expanded into manufacture. I had hopes of being able to induce Messrs. Penn & Sons to engage in such a manufacture. But as they have not found this compatible with their other occupations, it is now proposed to erect a special establishment for the purpose. The time has at length arrived at which some step of the kind is indispensable. High-speed engines require to be specially well made, with special materials and special skill. Without special tools good work is costly. But with them good work is as cheap as bad.

Supposing a good and cheap small engine to be available—an engine that will be strong, simple, safe, light, noiseless, and economical in fuel—not only would all its industrial applications be extended, but it would find a new and wide sphere of usefulness in ministering to domestic wants, one of the most widely pervading of which is the want of a simple motive-power. In American hotels steam engines have long been employed for brushing boots and cleaning knives. They are the docile and inexpensive Helots of the age, and the domestic production of the electric light is a new and important sphere for their energies. But besides these functions a domestic engine may be employed in roasting meat, driving washing machines and mangles, driving sewing machines, in brushing hair, in preparing aerated waters, and in the country for pumping, for sawing wood, and for performing many other laborious operations. A steam engine may be made to cool houses in summer and to warm them in winter, to maintain fountains in conservatories, to work punkahs, to produce ice, and to create and maintain a vacuum in safes for the preservation of meat. For such purposes the engine must obviously be of the simplest, most compact, and most inexpensive character, and should be attached to the boiler, so that the whole may be lifted in a piece, like a hall stove. The boiler should be provided with a self-acting feed of water, and the fuel should be gas, which has only to be lighted to ena ble the engine to be put into operation. Gas companies will find ample compensation for the loss of their lighting function in the creation of a new heating function, which will become larger and more remunerative than the lighting has ever been. Instead of extracting from the coal only the illuminating gases, the whole fuel should be turned into combustible gas by the aid of superheated steam, and all the fires of houses could be maintained by this cheap gas burning in jets amid pumice, which it would keep red-hot. There would then be neither dust from grates nor smoke from chimneys, and the gas works would supply the fuel that is necessary for the generation of the electric light.

I cannot pretend in this brief notice to enumerate all the improvements which the steam engine of the future should comprehend. But one essential quality is, that the boiler shall not be liable to internal incrustation, and that there shall be abundant facilities for easily cleaning

it out. Most waters contain a certain proportion of lime, which is precipitated by boiling, and in tea-kettles this lime forms an internal crust, which is termed "rock." Such incrustation hinders the transmission of heat through the metal of a boiler, and is injurious in various ways. But there are known means of preventing its formation, and in the "steam engine of the future" it is an indispensable feature that these means shall be embodied.

The application of the steam engine to the propulsion of carriages, omnibuses, and cabs is now only hindered by its too heavy weight and too high cost. Asphalte pavements, which are objectionable for horses, afford for steam carriages a surface as eligible for easy traction as a railway, and without any countervailing fault. All wheeled vehicles, whether required to travel at a high or at a low speed, will be propelled by steam instead of horses as soon as the steam engine is made sufficiently light and sufficiently cheap to warrant the substitution. Lifeboats, instead of being open boats propelled by a number of men, should be decked boats propelled by a steam engine, and managed by only two men, one to steer the boat and the other to attend to the engine. Such boats should be propelled by a water-jet which will always act, whatever may be the roughness of the sea, and whether the stern of the boat is in or out of the water. The use of the steam engine for irrigation in connection with the centrifugal pump is an application of which the sphere is limited only by the cost and the deficient portability of the apparatus. To render the class of small engines so much more portable, so much more simple, and so much less costly as to remove the existing impediments to their use may certainly be accounted one of the most important problems of the present time, and I trust it is not presumptuous to hope that the cursory hints here given may accelerate the desired solution.

ON THE SHAPE AND SIZE OF THE EARTH.*

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II.—THE EARTH AS A SPHEROID.

As an oblate spheroid is a volume generated by the revolution of an ellipse about its minor axis, the equator and all the sections of the spheroid parallel to the equator are circles, and all sections made by planes passing through the axis of revolution are equal ellipses. Let a and b represent the lengths of the semi-major and semi-minor axes of this meridian ellipse, which are the same as the semi-equatorial and semi-polar diameters of the spheroid; when the values of a and b have been found all the other dimensions of the ellipse and the spheroid become known. At first we must understand the properties of the ellipse, then combining some of these with the data deduced by measurements we find, as was done in the last lecture for the circle, the form and size of the earth's meridian section.

The eccentricity and ellipticity of an ellipse are merely two fractions, the first defined by the equation

$$e=\frac{\sqrt{a^2-b^2}}{a}$$

and the second by

$$f=\frac{a-b}{a}$$

or in other words the eccentricity e is the distance between the foci divided by the major axis, and the ellipticity f is the amount of flattening at one of the poles divided by the semi-major axis. The relation between these two fractions is

$$f=1-\sqrt{1-e^2}$$

or

$$e=\sqrt{2f-f^2}.$$

From the definitions of e and f we may express b in terms of a as follows:

$$b=a\sqrt{1-e^2}$$

or

$$b=a(1-f).$$

The two quantities relating to the

* Three lectures originally prepared for the Civil Engineering Students of Lehigh University, as introl ductory to a course in Geodesy.

ellipse that we shall need most particularly to use are the length of the quadrant and of the radius of curvature at any point. These are deduced in mathematical discussions on the ellipse, with which you are familiar; we here simply note their values and consider them as proved. The length of the quadrant is

$$q=\frac{a\pi}{2}\left(1-\frac{e^2}{4}-\frac{3e^2}{64}-\cdots\right)$$

or perhaps more conveniently

$$q=\frac{a\pi}{2}\left(1-\frac{f}{2}+\frac{f^2}{16}-\cdots\right).$$

If l be the latitude of any point on the meridian ellipse, the radius of curvature of the curve at that point is

$$r=\frac{a(1-e^2)}{\sqrt{(1-e^2\sin^2 l)^3}}.$$

For the equator, where $l=0°$, this has its least value $\frac{b^2}{a}$, but for the poles where $l=90°$ it has its greatest value $\frac{a^2}{b}$. Now in determining the form and size of the ellipse we may seek a and b or any two convenient functions of a and b. Those usually employed are a and e; when these have been found, b and q and f and r are also known from the above equations.

Were the earth a perfect sphere, one arc of a meridian measured with precision would be enough to deduce the value of its radius. As it is, however, plainly a spheroid, and as a spheroid requires two dimensions for establishing its size, it would seem that two measured arcs of meridians are at least required. Let m_1 and m_2 be the measured lengths of two meridian arcs, φ_1 and φ_2 their amplitudes, that is, the number of degrees of latitude between their northern and southern extremities, l_1 and l_2 their middle latitudes, r_1 and r_2 the radii of curvature of their middle points. Regarding these arcs as arcs of circles their radii of curvature, as shown in the last lecture, are

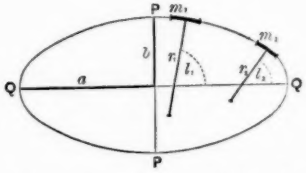
$$r_1=57.29578\frac{m_1}{\varphi_1}$$

$$r_2=57.29578\frac{m_2}{\varphi_2}.$$

Considering now the middle points of these arcs as lying upon the circumference of an ellipse whose semi-major axis is a and eccentricity e, these radii are

$$r_1=\frac{a(1-e^2)}{\sqrt{(1-e^2\sin^2 l_1)^3}}$$

$$r_2=\frac{a(1-e^2)}{\sqrt{(1-e^2\sin^2 l_2)^3}}$$



Equating these values gives the two following conditions:

$$57.29578\frac{m_1}{\varphi_1}=\frac{a(1-e^2)}{\sqrt{(1-e^2\sin^2 l_1)^3}}$$

$$57.29578\frac{m_2}{\varphi_2}=\frac{a(1-e^2)}{\sqrt{(1-e^2\sin^2 l_2)^3}}$$

which contain eight quantities all known except a and e. It is evident that a and e will be the more accurately determined the nearer to the pole one of the arcs be taken, and the nearer to the equator the other. To solve these equations observe that if the first be divided by the second, we obtain an equation containing e^2 alone, from which

$$e^2=\frac{1-\left(\frac{m_1\varphi_2}{m_2\varphi_1}\right)^{\frac{2}{3}}}{\sin^2 l_2-\left(\frac{m_1\varphi_2}{m_2\varphi_1}\right)^{\frac{2}{3}}\sin^2 l_1}.$$

Then to find a place the value of e in either of the above equations and solve for a.

For an example let us take the two arcs measured about the year 1737, by astronomers in the employ of the French Academy, one in Lapland and the other in Peru. The data are as follows:

Lapland Arc:
Length = 92778 toises = 180827.7 meters.
Lat. of N. end = +67° 8′ 49.″83
Lat. of S. end = +65 31 30.26

Peruvian Arc:
Length = 176875.5 toises
= 344735.9 meters.
Lat. of N. end = +0° 2′ 31.″39
Lat. of S. end = −3 4 32.07.

Calling the Lapland Arc No. 1 and the Peruvian No. 2, we find l_1 and l_2 by tak-

ing the mean of the two latitudes in each case, and φ_1 and φ_2 by taking their difference. Then

$$m_1 = 180827.7 \text{ meters}$$
$$\varphi_1 = 1.^\circ 622102$$
$$l_1 = +66^\circ\ 20'\ 10.''05$$
$$m_2 = 344735.9 \text{ meters}$$
$$\varphi_2 = 3.^\circ 117628$$
$$l_2 = -1^\circ\ 31'\ 0.''34.$$

Substituting these values in the above expression for e^2 we find

$$e^2 = 0.00643506$$

or

$$e = 0.08022.$$

Inserting this value of e^2 in either of the original equations and solving for a we find

$$a = 6376568 \text{ meters.}$$

From the value of e^2 we find also

$$f = 0.0032228$$

and then

$$b = 6356020 \text{ meters}$$
$$q = 10000150 \text{ meters.}$$

It is often customary to state the value of the ellipticity as a vulgar fraction whose numerator is unity, since thus a clearer idea is presented of the flattening at the poles. In this case the fraction is

$$f = \frac{1}{310.3}$$

that is, the amount of the flattening at one of the poles is about $\frac{1}{310}$th of the equatorial radius. In the same way the eccentricity may be written

$$e = \frac{1}{12.5}$$

or the distance of the focus of the ellipse from the center is about $\frac{1}{12.5}$th of the equatorial radius. These fractions are both somewhat too small for the actual spheroid, as will be shown in future paragraphs.

Let us now go back to the year 1745 or thereabouts, when, it will be remembered, the results of the surveys instituted by the French Academy became known. These results have been stated in the previous lecture, but it may be well to note them here again.

Arc.	Mean lat.	Length of 1° of latitude.
		Meters.
Lapland	+66°20′	111949
France	+49 22	111212
Peru	− 1 34	110565

By the method above explained, or by other similar methods, these data may be combined in three different ways to deduce the shape and size of the earth, assuming it to be a spheroid of revolution. These combinations gave for the ellipticity:

From Lapland and French Arcs, $\frac{1}{144}$
From Lapland and Peruvian Arcs, $\frac{1}{310}$
From French and Peruvian Arcs, $\frac{1}{304}$.

Now if the earth be a spheroid of revolution, and if the measurements be well and truly made, then these values of the ellipticity should be the same. As, however, they disagree, the conclusion is ea y to make that either the assumption of a spheroidal surface is incorrect or the surveys are inaccurate. To settle this question there were measured in the following fifty years a number of meridian arcs in different parts of the world, one in South Africa by Lacaille, one in Italy by Boscovich, one in America by Mason and Dixon, one in Hungary by Liesganig, and one in Lapland by Svanberg, while in France, England and India, geodetic surveys furnished also the materials for the deduction of other arcs. Most important of all was the investigation undertaken by the French for the derivation of the length of the meter, the surveys for which with the accompanying office-work lasted from 1792 to 1807. This work was under the charge of the celebrated astronomers Delambre and Méchain, and the meridian arc extended from the latitude of Dunkirk on the north to that of Barcelona on the south, embracing an amplitude of nearly ten degrees. In this survey the methods for the measurement of bases and angles were greatly improved, and in fact here approached for the first time to modern precision. The results, as finally published in 1810, were,

length of arc = 551584.7 toises
amplitude = 9° 40′ 23.″89

and these were combined with the corre sponding values in the Peruvian arc to find the ellipticity. The combination gave

$$f = \frac{1}{334}$$

and then the length of the quadrant was found to be

$$q = 5130740 \text{ toises.}$$

Now it had been established by law that the meter should be one ten-millionth part of the quadrant. Hence

$$1 \text{ meter} = 0.513074 \text{ toises}$$

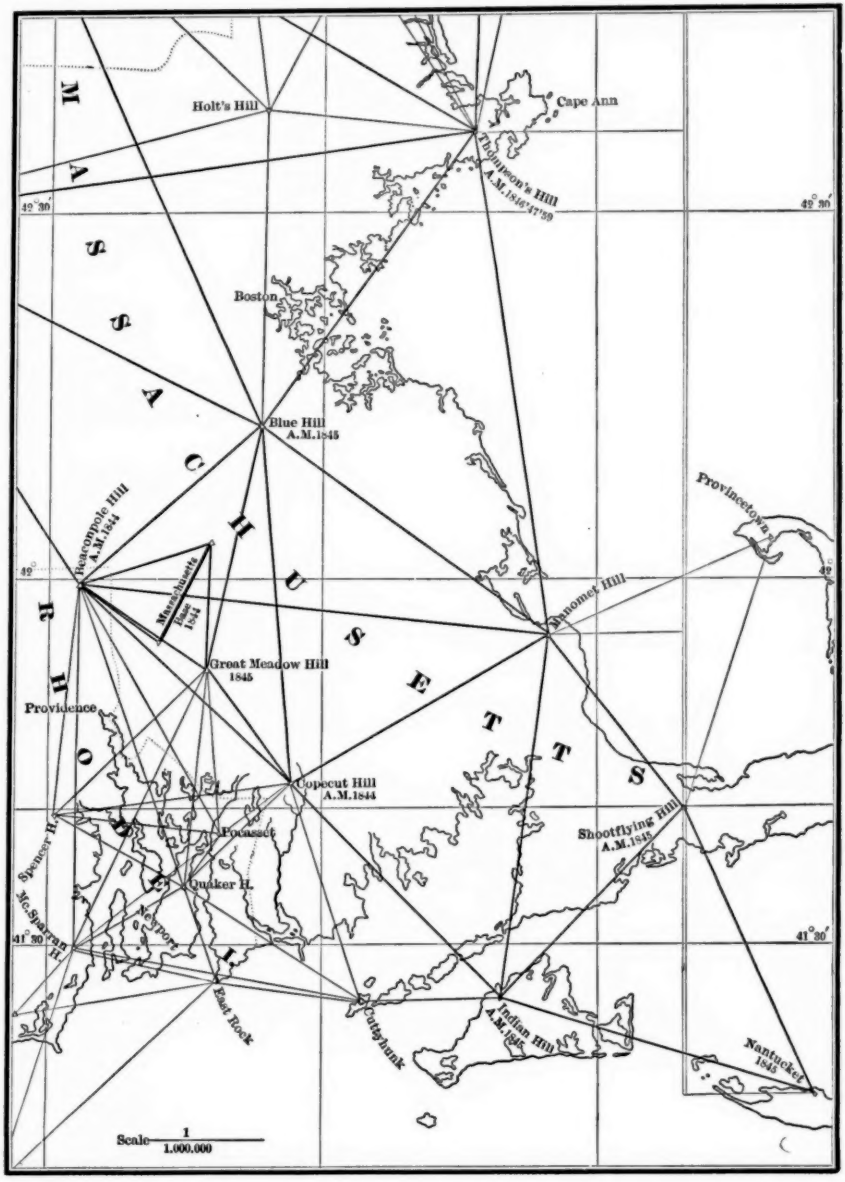
and of course $q = 10\,000\,000$ meters.

During the present century the measurement of meridian arcs has generally been carried on only in connection with the triangulations which form the basis of extensive topographical surveys. Central Europe is now covered with a net of triangles, and the same is true of portions of Russia, India and the United States. To obtain a general idea of the processes involved in such work, let us consider for a few moments a portion of the triangulation executed by the United States Coast Survey in New England, and which has furnished a meridian arc of about 3° 22′ in amplitude, or about 233 miles in length. Sketch No. 3, in the Coast Survey Report for 1875, exhibits the plan of the triangulation.* Near the north-eastern corner of the State of Rhode Island you see a line called the Massachusetts base, which was measured along the track of the Boston and Providence railroad in 1844, with a base apparatus consisting of four bars placed in contact with each other in a wooden box, and provided with micrometer microscopes by which wires could be brought into optical contact with the ends of the bars and with eight thermometers to ascertain the temperature. The length of the base line is nearly $10\frac{1}{2}$ miles, and its measurement occupied about three months, the exact result corrected for temperature, inclination, and elevation above mean ocean level being 17326.376 U. S. meters with a probable error of 0.036 meters. About 295 miles north-easterly is the Epping base, and 230 south-westerly is the Fire Island base, which have also been measured with the same careful attention. From the comparison of the measured lengths of these base lines with their lengths as computed through the triangulation, published in the Coast Survey Report for 1865, we extract the following values of the Massachusetts base:

Measured length.....17326.376 meters
Calculated from Epping
base.....17326.528 "
Calculated from Fire
Island base.....17326.445 "

which show the great accuracy of the work, since the differences of these results exhibit the accumulated errors of all the angle work between the bases as well as those of the linear measurements. The map also shows how from the base line the position of Beaconpole Hill is determined, then that of Great Meadow Hill, and how from these two the triangulation is extended to Blue Hill, and thence onward in all directions. To select these stations a careful reconnaissance was made, the proper tripods and signals were erected, and then there was placed over each station in succession a great theodolite with a circle thirty inches in diameter, graduated to five minutes and reading to single seconds by three micrometer microscopes, and with it skilled observers measured all the horizontal angles, each being taken many times on different parts of the arc and in different positions of the telescope, so as to eliminate the instrumental errors. At some of the stations too astronomical theodolites were placed to determine, by observations on circumpolar stars, the meridian, and thence the azimuths of the sides of the triangles, and to find the latitudes a portable zenith telescope was used to measure the difference of the zenith distances of many carefully selected pairs of stars. Longitudes of some of the points are found by comparing with the electric telegraph the local times with that of some established observatory. From these stations of the larger or primary triangles there are formed smaller or secondary triangles, from which the plane table surveys and other topographical work extend out all along the coast line. But before the hydrographic charts can be published, a great deal of computation is necessary. The observed angles must be adjusted by the method of least squares, so as to balance in the most advantageous way the small irregular errors of observation. From the bases the lengths of all the sides of the triangles are found, the spherical excesses computed, the adjustments made, and, finally, the latitudes and longitudes

* Fig. 6 is a copy of a small part of this sketch, and shows only the southern part of the meridian arc.


MASSACHUSETTS
RHODE
Holt's Hill
Cape Ann
Thompson's Hill
A.M.1816'47"39
42° 30'
Boston
Blue Hill
A.M.1845
Provincetown
Peaked Hill
A.M.1844
42°
Massachusetts
Base
1844
Prospect Hill
Great Meadow Hill
1845
Providence
Copecut Hill
A.M.1844
Spencer H.
Focussett
Shootflying Hill
A.M.1845
Quaker H.
Mc.Sparran H.
41° 30'
Newport
East Rock
Cuttyhunk
Indian Hill
A.M.1845
Nantucket
1845
Scale 1/1.000.000

of each station determined. If now a chain of triangles runs approximately north and south for some distance, these calculations can be readily extended so as to deduce a meridian arc. In the map before us, you will notice two parallel lines drawn through the station Shootflying Hill. This is an arc of a meridian deduced from the New England primary triangulation, by methods explained in the Coast Survey Report for 1868. Its southern extremity is in the latitude of Nantucket, and its northern in that of Farmington, Maine. You can see in the map the broken lines drawn perpendicular to the meridian from the several stations; the portions intercepted between these perpendiculars are the meridian distances corresponding to the differences of latitude. The following are the numerical results:

Stations.	Observed Astr'nomical Latitudes.	Distances between parallels.
		meters.
Farmington.....	44°40′12.″06	58567.41
Sebattis.....	44 8 37. 60	42718.32
Mt. Independence..	43 45 34. 43	59535.58
Agamenticus.....	43 13 24. 98	67971.93
Thompson.....	42 36 38. 28	76002.37
Manomet.....	41 55 35. 33	70429.77
Nantucket.....	41 17 32. 86	

The total length of the arc is 375225.38 meters, with a probable error of 1.3 meters. The probable error of an observed astronomical latitude does not exceed 0.1 second. From the whole arc the length of one minute is found to be 1851.6 meters, with a probable error of 0.6 meters, and the length of one degree in the middle latitude of the arc is 111096 meters, with a probable error of 36 meters.

It is impossible to regard attentively these accurate measures, without a feeling of wonder at the remarkable growth of geodetic science during the present century, not only in instrumental precision, but in theoretical methods of computation. A hundred years ago, for instance, the measurement of the angles of geodetic triangles was so rude that the spherical excess remained undetected, and the processes of adjustment by the method of least squares were entirely unknown. The zenith telescope for latitude observations, the electric telegraph for longitude determination, the self compensating base apparatus, the method of repetitions in angle measurement, the comparison of the precision of observations by their probable errors, and their adjustment by minimum squares, the theory of speroidal geodesy, all these and many other improvements have been introduced, and pefected in the present century, almost within the memory of men now living.

We have explained above a method by which the size of the earth regarded as an oblate spheroid, may be found by the combination of two measured parts of meridian arcs, and we have also said that at the year 1760, or thereabouts, such combinations of several arcs, taken two by two, gave discordant values for the ellipticity and the length of the quadrant, and that hence it became evident, that either the earth's meridian section was not an ellipse, or that the measurements were not accurately made. Towards the end of the last century, many attempts were made at rational combinations of the accumulating data, the most important, perhaps, being one by Boscovich in 1760, and two by Laplace published in 1793 and 1799 respectively. In order to obtain a clear idea of the problem, let us state the very data used by Laplace in his first discussion. The numbers in the last column are found by dividing the linear length of each arc in toises by its amplitude in degrees. Now if we consider short lengths as arcs of a circle, they are directly proportional to the lengths of the radii at their middle points, and if we take these middle points as situated on an ellipse, having the earth's equatorial and polar diameters for its axes, the lengths of the degrees are directly proportional to the corresponding radii of

No.	Locality of arc.	Middle latitude.	Length of one degree.
			toises.
1	Lapland.....	66° 20′	57405
2	Holland.....	52 4	57145
3	France.....	49 23	57074½
4	Austria.....	48 43	57086
5	France.....	45 43	57034
6	Italy.....	43 1	56979
7	Pennsylvania..	39 12	56888
8	Peru.....	0 0	56753
9	CapeGood Hope	33 18	57037

curvature of the ellipse. Thus if d be the length of any degree, D the length of one at the equator, and r and R the corresponding radii of curvature, we have

$$\frac{D}{d}=\frac{R}{r}$$

Inserting here for r, its value at latitude l, and R its value at the latitude 0°, as given in the early part of this lecture, we find

$$d=D\,(1-e^2\sin^2 l)^{-\frac{3}{2}}$$

which, after development by the binomial formula, may be written

$$d=D(1+\tfrac{3}{2}e^2\sin^2 l+\tfrac{15}{8}e^4\sin^4 l+\ldots.)$$

Now D, the length of one degree at the equator, may be expressed in terms of the ecentricity e, and the semi-equatorial diameter, a. Thus

$$D=R\,\frac{\pi}{180}=\frac{b^2}{a}\cdot\frac{\pi}{180}=\frac{\pi a}{180}(1-e^2)$$

and inserting this, we find for d

$$d=\frac{\pi a}{180}(1-e^2)(1+\tfrac{3}{2}e^2\sin^2 l+\tfrac{15}{8}e^4\sin^4 l+\ldots).$$

It thus appears that the length of a degree can be expressed by an equation of the form

$$d=M+N\sin^2 l+P\sin^4 l+\ldots\ldots$$

in which

$$M=\frac{\pi a(1-e^2)}{180}$$

$$N=\frac{3\pi a e^2(1-e^2)}{360}$$

$$P=\frac{15\pi a e^4(1-e^2)}{14400}$$

$$\ldots=\ldots\ldots\ldots$$

and Laplace, in discussing the above data, considered that it was unnecessary to include powers of e higher than the square, and hence that

$$d=M+N\sin^2 l,$$

expressed the length of one degree of the meridian ellipse. Now the problem is this: to deduce from the above seven meridian arcs the values of M and N, so as to obtain an expression for d, the length of one degree of latitude at the latitude l, and then from these values of M and N to find a and e, and all the other elements of the spheroid. And the first step must be to insert in the formula, the values of d and l for each of the arcs. Thus for arc No. 1,

$$d=57405 \text{ toises}$$
$$l=66^\circ\ 20'$$
$$\sin l=0.93565$$
$$\sin l^2=0.83887$$

and $57405=M+0.83887N$

In this manner we form the nine following equations:

$$\begin{aligned}
57405 &= M+0.83887N\\
57145 &= M+0.62209N\\
57074\tfrac{1}{2} &= M+0.57621N\\
57086 &= M+0.56469N\\
57034 &= M+0.51251N\\
56979 &= M+0.46541N\\
56888 &= M+0.39946N\\
56753 &= M+0.00000N\\
57037 &= M+0.30143N
\end{aligned}$$

and from them the values of M and N are to be determined. Now two equations are sufficient to find two unknown quantities, and hence it seems that no values of M and N can be given that will exactly satisfy all of the nine equations. The best that can be done is to find such values as will satisfy them in the most reasonable manner, or with the least discrepancies. To make this idea more definite suppose that the second members of these equations be transposed to the first, giving equations of the form

$$d-M-N\sin^2 l=0,$$

then since M and N can not exactly reduce them to zero, we may write

$$\begin{aligned}
57405 &-M-0.83887N=x_1\\
57145 &-M-0.62209N=x_2\\
57074\tfrac{1}{2} &-M-0.57621N=x_3\\
&\text{etc,}\qquad\text{etc,}\qquad\text{etc,}
\end{aligned}$$

in which x_1, x_2, x_3, etc., are small errors or residuals. Now Laplace, following the idea of Boscovich, conceived that the most reasonable values of M and N were those which would render the algebraic sum of the errors, x_1, x_2, x_3, etc., equal to zero, and also make the sum of the same errors, all taken with the plus sign, a minimum. By introducing these two conditions, he was able to reduce the nine equations to two, from which he found

$$M=56753 \text{ toises},$$
$$N=613.1 \text{ toises},$$

His value of the length d in toises of one degree at the latitude l, was hence.

$$d=56753+613.1\sin^2 l$$

From the values of M and N, it was now easy to find the ellipticity f. Thus, from

the above definitions of M and N, we have

$$\frac{N}{M}=\frac{3}{2}e^2$$

from which

$$e^2=\frac{2\times 613.1}{3\times 56753}=0.007202$$

and then $f=0.0036=\frac{1}{278}$.

From the expression for either M or N it is also easy to find a the semi-major axis, whence b the semi-minor axis, and q the quadrant of the ellipse become known. The last step in Laplace's investigation is the comparison of the observed values of the lengths of some of the degrees with those found from his formula for d. For the Lapland arc, for instance, observation gives

$$d=57405 \text{ toises},$$

while computation gives

$$d=56753+613.1\sin^2 66°20'=57267.3$$

the difference, or error, being

137.7 toises,

a distance equal to about 268 meters, or nearly 9 seconds of latitude. These errors, says Laplace, are too great to be admitted, and it must be concluded that the earth deviates materially from an elliptical figure.

At the beginning of the present century it was the prevailing opinion among scientists, founded on investigations similar to that of Laplace, that the contradictions in the data derived from meridian arcs, when combined on the hypothesis of an oblate spheroidal surface, could not be attributed to the inaccuracies of surveys, but must be due in part, at least, to deviations of the earth's figure from the assumed form. This conclusion, although founded on data furnished by surveys that would now-a-days be considered rude, has been confirmed by all later investigations, so that it can be laid down as a demonstrated fact that this earth is not an oblate spheroid. And yet it must never be forgotten that the actual deviations from that form are very small when compared with the great size of the globe itself. In fully half the practical problems into which the shape of the earth enters, it is sufficient to consider it a sphere; in others its variation from a spherical form must be noticed, and there we regard it as spheroidal; cases where it would be requisite to regard its deviation from the spheroidal form will rarely if ever occur in any engineering question, yet for the sake of science we feel curious to determine the laws governing it, and these perhaps may at some future time be determined. Now, in the early part of the present century it was agreed by all, notwithstanding the discrepancies of measurements, that for the practical purposes of mathematical geography and geodesy it was highly desirable to determine the elements of an ellipse agreeing as closely as possible with the actual meridian section of the earth. Hence various methods of combination were tried, and as new data accumulated they were quickly added to the store already on hand, crowding out gradually, to be sure, the older data of less accurate surveys. The most important one of these methods of combination, which is the one now exclusively used for the discussion of precise measurements, was the method of least squares—and a few words must be said concerning its history and explanatory of its processes.

In the year 1805 Legendre announced a process for the adjustment of observations founded upon the principle that the sum of the squares of the residual errors should be made a minimum, and which he named "method of least squares." He gave no proof of the advantage of the principle, but stated it merely as one which seemed to him to be the simplest and the most general and to secure the most plausible balancing of errors of observation. He deduced some practical rules for its use and applied it to a numerical example which, it is interesting to observe, was a discussion of the earth's elliptic meridian as resulting from five portions of the long French arc. But in 1809 Gauss published a theoretical investigation in which he showed from the theory of probability that this method gave the most probable results of the quantities sought to be determined, provided that the observations were subject only to accidental errors—that is, to errors governed by no laws but those of chance. This proof caused the method to be immediately accepted by mathematicians as the only rational process for the adjustment of measurements, and in the following quarter of a century it was

fully developed by the labors of Gauss, Bessel and others. And here it should not be forgotten that in our own country and in the year 1808, one year in advance of Gauss, Adrian published a proof of the same principle, which unfortunately remained unknown to mathematicians for more than sixty years. To Bessel is due the first idea of the comparison of the accuracy of observations by their probable errors and also many valuable applications of the method to geodetic measurements. It has been truly said that the method of least squâres is "the most valuable arithmetical process that has been invoked to aid the progress of the exact sciences;" for the values deduced by it are those which have the greatest probability. With the aid of the theory of probable error the precision of the observations is readily inferred, and uniformity is secured in processes of adjustment and comparison. To explain the operation of the method, or rather one of its most commonly used operations let us take a numerical example, and let it be a problem relating to the determination of the earth's ellipticity by pendulum experiments. The following are the data—thirteen values of the length of a second's pendulum in various parts of the earth as observed by Sabine in the years 1822–24:

Place.	Latitude.	Length of seconds pendulum.
		English inches.
Spitzbergen.	+79°49′58″	39.21469
Greenland..	74 32 19	39.20335
Hammerfest.	70 40 5	39.19519
Drontheim..	63 25 54	39.17456
London.....	51 31 8	39.13929
New York..	40 42 43	39.10168
Jamaica....	17 56 7	39.03510
Trinidad....	10 38 56	39.01884
Sierra Leone.	8 29 28	39.01997
St. Thomas..	0 24 41	39.02074
Maranham..	−2 31 43	39.01214
Ascension...	7 55 48	39.02410
Bahia.....	12 59 21	39.02425

The ellipticity of the earth may be derived from these observations by means of a remarkable theorem published by Clairaut in 1743, namely

$$\frac{g}{G}=1+(\tfrac{5}{2}k-f)\sin^2 l,$$

in which G is the force of gravity at the equator, g that at the latitude l, k the ratio of the centrifugal force at the equator to gravity, and f the ellipticity of the earth regarded as an oblate spheroid. This theorem is limited only by the conditions that the form of the earth is a spheroid of equilibrium assumed in the rotation on its axis, and that its material is homogeneous in each spheroidal stratum. Now, the length of a pendulum beating seconds is proportional to the force of gravity, hence if S represent the length of such a pendulum at the equator and s the length at the latitude l, the theorem may be also written

$$\frac{s}{S}=1+(\tfrac{5}{2}k-f)\sin^2 l.$$

We see then that

$$s=S+T\sin^2 l$$

in which

$$T=S(\tfrac{5}{2}k-f)$$

is a general expression for the length of a second's pendulum. When T and S have been found, their ratio gives the value of $\frac{5}{2}k-f$. and then f the ellipticity becomes known, since k is easily determined with an error of less than half a unit in its third significant figure; (see your elementary text-book on mechanics or astronomy for a proof that $k=\frac{1}{289}$). For each one of the above observations we next write an observation equation, by substituting for s and l their values in the formula

$$s=S+T\sin^2 l.$$

Thus, for the first

$$s=39.21469$$
$$l=79°\ 49'\ 58''$$
$$\sin l=0.9842665$$
$$\sin^2 l=0.9688402$$
$$39.21469=S+0.9688402T$$

In this manner we find the following thirteen observation equations:

$$39.21469=S+0.9688402T$$
$$39.20335=S+0.9289304T$$
$$39.19519=S+0.8904120T$$
$$39.17456=S+0.7999544T$$
$$39.13929=S+0.6127966T$$
$$39.10168=S+0.4254385T$$
$$39.03510=S+0.0948286T$$
$$39.01884=S+0.0341473T$$
$$39.01997=S+0.0218023T$$
$$39.02074=S+0.0000515T$$
$$39.01214=S+0.0019464T$$
$$39.02410=S+0.0190338T$$
$$39.02425=S+0.0505201T$$

Now, since the left hand members of these equations are affected by errors of observations it will not be possible to find values for S and T that will exactly satisfy all the equations; the best that we can do is to find their most probable values, and this is done by the following rule, which you will find proved in all books on the method of least squares: Deduce a normal equation for S by multiplying each observation equation by the coefficient of S in that equation, and adding the results; deduce also a normal equation for T by multiplying each observation equation by the coefficient of T in that equation and adding the results; thus we shall have two normal equations each containing two unknown quantities, and the solution of these equations will give us the most probable values of S and T. In this case the coefficient of S in each of the equations is unity, multiplying each equation by unity leaves it unchanged, and we have simply to take their sum to get the first normal equation,

$$508.1839D = 13S + 4.8487021T.$$

To find the second normal equation we multiply the first observation equation by 0.9688402, the second by 0.9289304, and so on, and by addition of these results we have

$$189.944469 = 4.8487021S + 3.7043941T.$$

The solution of these two normal equations gives

$$S = 39.01568 \text{ English inches}$$
$$T = 0.20213 \quad " \quad "$$

as the most probable values that can be deduced from the thirteen observations. Hence the length of the seconds pendulum at any latitude l may be written

$$s = 39.01568 + 0.20213 \sin^2 l.$$

Lastly, we find the ellipticity of the earth by the formula

$$f = \tfrac{5}{2}k - \frac{T}{S}$$

whence $$f = 0.0086505 - 0.0051807$$

or $$f = \frac{1}{288.2}$$

Before leaving the subject of the pendulum, which we have been obliged to treat very briefly, we will mention that numerous observations of this kind have been made in various parts of the earth, and that the value of the ellipticity deduced from them is $\frac{1}{288.9}$.

During the present century there have been published many investigations and combinations by the method of least squares of the data furnished by the measurement of meridian arcs. The principal results of the most important of these made on the hypothesis of a spheroidal figure are given in the following table:

Year.	By whom.	Ellipticity.	Quadrant in meters.
1819	Walbeck	1:302.8	10 000 268
1830	Schmidt	1:297.5	10 000 075
1830	Airy	1:299.3	10 000 976
1841	Bessel	1:299.2	10 000 856
1856	Clarke	1:298.1	10 001 515
1863	Pratt	1.295.3	10 001 924
1866	Clarke	1:295	10 001 887
1868	Fischer	1:288.5	10 001 714
1872	Listing	1:289	10 000 218
1878	Jordan	1:286.5	10 000 681
1878	Clarke	1:293.5	10 001 872

Let us now endeavor to state briefly how such calculations are made. The principle of the method of least squares, it will be remembered, requires that the sum of the squares of the errors of observation shall be rendered a minimum. The first inquiry then is, where are the errors of observation in a meridian arc, are they in the linear distance or in the angular amplitude? As long ago as a hundred years, it was suspected that the discrepancies in such surveys were due to deflections of the plumb lines from a vertical, caused by the attraction of mountains, whereby observers were deceived in the position of the zenith and the true level of a station, and hence deduced false values of its latitude. It needs indeed not an extensive knowledge of the modern accurate methods of geodesy to become convinced that the errors in the linear distances are very small; on the U. S. Coast Survey, for instance, the probable error in the computed length of any side of the primary triangulation is its $\frac{1}{288000}$th part, which amounts to less than a quarter of an inch in a mile, or two feet in a hundred miles. The probable error of observation in the latitude of a station is also small, yet it is easy to see that it may be affected with a constant error,

due to the deviation of the vertical from the normal to the spheroid. To illustrate, let the annexed sketch represent a portion of a meridian section of the earth. O is the ocean, M a mountain and A a latitude station between them; *sss* is a part of the meridian ellipse coinciding with the ocean surface; AC represents the normal to the ellipse, and AH, perpendicular to AC, the true level for the station A. Now owing to the attraction of the mountain M, the plumb line is drawn southward from the normal to the position A*c*, and the apparent level is depressed to A*h*. If AP be parallel to the earth's axis, and hence pointing toward

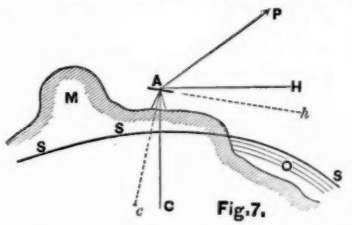


Fig. 7.

the pole, the angle PAH is the latitude of A for the spheroid *sss*; but as the instrument at A can only be set for the level A*h* the observed latitude is PA*h*, which is greater than the true by the angle HA*h*. These differences or errors are usually not large—rarely exceeding ten seconds—yet, since a single second of latitude corresponds to about 31 meters or 101 feet, it is evident that the error in the linear distance of a meridian arc is very small, in comparison with that due to a few seconds of error in the difference of latitude. In treating such measurements by the method of least squares we hence regard the distances as without error, and state observation equations which are to be solved by making the sum of the squares of the errors in the latitudes a minimum. Such equations may be stated by writing an expression for an arc of an ellipse in terms of the observed latitudes l_1 and l_2, and measured length of a meridian arc, then in this placing l_1+x_1 and l_2+x_2, instead of l_1 and l_2, the letters x_1 and x_2 denoting the errors in latitude at the stations 1 and 2. The expression will take the form

$$x_2-x_1=m+n\mathrm{S}+p\mathrm{T}$$

in which m, n and p are known functions of the observed quantities, and S and T are known functions of the elements of the ellipse whose values are sought. If there are several latitude stations in a single arc, as is generally the case, one of them should be taken as a reference station, and each error written in terms of the error there. Thus if there be four latitude stations, we write

$$\begin{aligned} x_1&=x_1\\ x_2&=x_1+m+n\mathrm{S}+p\mathrm{T}\\ x_3&=x_1+m'+n'\mathrm{S}+p'\mathrm{T}\\ x_4&=x_1+m''+n''\mathrm{S}+p''\mathrm{T} \end{aligned}$$

In like manner there will be a similar series for each arc, each series containing as many equations as there are latitude stations. The first members of these are the latitude errors in regular order, and the sum of the squares of these are to be made a minimum to find the most probable values of S and T; this is done by deriving normal equations for the left hand members by the usual rule. These normal equations will contain as unknown quantites S and T and as many errors, x_1, x_2, etc., as there are meridian arcs. When these equations have been solved it is easy to deduce from S and T the values of the elements of the ellipse. Such in brief is the method; but to explain all the details of calculation with the devices for saving labor, and ensuring accuracy is not possible here—it would indeed be matter enough for more than a whole lecture.

The most important, perhaps, of these discussions is that of Bessel, published in 1837, and revised in 1841 because in the meantime an error had been detected in the French survey. We call it the most important, not merely on account of the careful scrutiny given to all the data and the precise processes of computation employed, but also because its results have been since widely adopted and used in scientific works and geodetic literature. The material employed by Bessel consisted of ten meridian arcs—one in Lapland, one each in Russia, Prussia, Denmark, Hanover, England and France, two in India, and lastly, the one in Peru. The sum of the amplitudes of these arcs is about 50.5°, and they include 38 latitude stations. In the manner briefly described above there were written 38 observation equations, from which 12 normal equations containing 12 unknown

quantities, were deduced. The solution of these gave the elements of the meridian ellipse, and also the relative errors in the latitudes due to the deflections of the plumb lines. The greatest of these errors was 6.″45, and the mean value 2.″64. The spheroid resulting from this investigation is often called Bessel's spheroid, and the elements of the generating ellipse Bessel's elements; the values of these will be given below.

In 1866 Clarke of the British Ordnance Survey, published a valuable discussion, which included a minute comparison of all the standards of measure that had been used in the various countries. The data were derived from six arcs, situated in Russia, Great Britain, France, India, Peru and South Africa, including 40 latitude stations, and in total embracing an amplitude of over 76°. This investigation is generally regarded as the most important one of the last quarter of a century, and the values derived by it as more precise than those of Bessel. The Clarke spheroid, as it is often called, has been adopted in some of the geodetic calculations of the United States Coast Survey Office, and the constants and tables computed from Bessel's elements are now being changed to correspond with those of Clarke. It is hence necessary for the student of geodesy to be acquainted with the differences between the two spheroids, and in the following table the complete elements of the meridian ellipses of both are given:

	Bessel's Elements. 1841.	Clarke's Elements. 1866.
Semi-major axis a in meters	6 377 397	6 378 206
" " " English Feet	20 923 597	20 926 062
Semi-minor axis b in Meters	6 356 079	6 356 584
" " " English Feet	20 853 654	20 855 121
Meridian Quadrant in Meters	10 000 856	10 001 887
Eccentricity e	0.081 696	0.082 271
" e^2	0.006 674	0.006 768
Ellipticity f	$\frac{1}{299}$	$\frac{1}{295}$

From these it is easy to compute the radius of curvature of the ellipses for any latitude, and then to find the lengths of the degrees of latitude and longitude, which are required in the construction of map projections. We give a few of these values in order to exhibit more clearly the differences between the two spheroids:

Lat.	1 degree of latitude on the spheroid of	
	Bessel.	Clarke.
	Meters.	Meters.
90°	111 680	111 699
50°	111 216	111 229
45	119	131
40	023	033
35	929	937
30	841	848
25	762	768
0	110 564	110 567

For the lengths of the degrees of longitude, there is likewise a difference of about twelve meters in the results deduced from the elements of the two spheroids. For instance, at 50° and at 40° on the Bessel spheroid we have 71687 and 85384 meters as the lengths of one degree of the parallel, while the corresponding values for the Clarke spheroid are 71698 and 85396 meters, On a scale of $\frac{1}{1000}$, twelve meters would be 1.2 millimeters; but a sheet of paper exhibiting a whole degree must be several meters in width and length, and hence it would seem that for the practical purposes of map projection the differences between the two spheroids are too small to be generally regarded. The length in English feet of one degree of latitude at any latitude l on the Clarke spheroid is given by the expression

$$d = 364609.87 - 1857.14 \cos 2l + 3.94 \cos 4l$$

and the lengths of the degrees of longitude may be computed from the formula

$$365538.48 \cos l - 310.17 \cos 3l + 0.39 \cos 5l$$

and after dividing the constants by the number 3.28086933, they give the lengths in meters.

The form of the earth may also be deduced from measured arcs of parallels

between points whose longitude are known, but as yet geodetic surveys have not furnished sufficient material to effect a satisfactory discussion. It is evident that such arcs will have a particular value in determining whether or not the equator and the parallels are really circles. Regarding the form as spheroidal the elements may likewise be found from the length of a geodetic line whose end latitudes and azimuths have been observed. Such a line extending through the Atlantic States from Maine to Georgia, has been deduced from the primary triangulation of the United States Coast Survey, but its data and the results found therefrom have not yet been published. We learn, however, (from the Proceedings of the European International Geodetic Association) that its influence upon our knowledge of the figure of the earth is to but slightly increase the dimensions of Clarke's spheroid, without appreciably changing his value of the ellipticity.

By regarding the figure of the earth as one of equilibrium assumed under the action of forces due to its gravity and rotation when in a homogeneous fluid state, the value of the ellipticity may be computed from purely theoretical considerations. Newton deduced in this way the value $f=\frac{1}{230}$, and an investigation by Laplace proves that the ellipticity of a homogeneous fluid spheroid revolving about an axis, and whose form does not differ materially from that of a sphere, is equal to five-fourths of the ratio of the centrifugal force at the equator to the gravitative force. As this ratio is known to be $\frac{1}{289}$, the theorem gives $\frac{1}{231}$ for the ellipticity. But as this value is much too great the conclusion must be that the earth is not homogeneous.

Lastly, the shape of the earth may be found from astronomical observations and calculations. Irregularities in the motion of the moon were at first explained by the deviation of the earth from a spherical form, and then by precise measurement of the extent of the irregularities; the ellipticity was computed, the value determined by Airy being $\frac{1}{299}$. As the precession of the equinoxes is due to the attraction of the sun and moon on the excess of matter around the earth's equator, it would seem as if the figure of the globe might be found from that phenomenon also.

Looking back now over the historical facts, as here so briefly presented, we may observe that the values of the ellipticity f and of the length of the quadrant q, as deduced from geodetic surveys, have both exhibited a tendency to increase as the data derived from such surveys have become more precise and numerous. About the year 1805 their values, as adopted in the celebrated work for the establishment of the meter, were

$$f=\tfrac{1}{334} \quad q=10\ 000\ 000 \text{ meters.}$$

In 1841 the investigation of Bessel gave

$$f=\tfrac{1}{299} \quad q=10\ 000\ 856 \text{ meters,}$$

and in 1866 Clarke found

$$f=\tfrac{1}{295} \quad q=10\ 001\ 887 \text{ meters.}$$

In addition to this we should bear in mind that the combination of numerous pendulum observations give, with considerable certainty,

$$f=\tfrac{1}{289},$$

and this value, it seems not improbable to suppose, may perhaps be ultimately deduced from geodetic measures when they become more widely extended over the surface of the earth. For very many problems it will be found convenient to keep in mind the following round numbers:

$$\text{Ellipticity}=\frac{1}{17^2}$$

$$\text{Eccentricity}=\frac{1}{12}$$

$$\text{Quadrant}=10001 \text{ kilometers.}$$

The following mnemonic rule may perhaps be of some use in remembering the values of the semi-equatorial and semi-polar diameters a and b: keep in mind the number 6400 kilometers (which is a perfect square), then a is 22 kilometers and b is 44 kilometers less than this. In the form of an equation

$$a=(6400-22) \text{ kilometers,}$$
$$b=(6400-44) \text{ kilometers;}$$

and the difference $a-b$ equals 22 kilometers. To convert these distances into miles is easy enough if the number of miles in a kilometer is known, but if there be any difficulty in remembering this let it be held fast from the mnemonic analogy

that 5280 feet make one mile, but that 3280 feet make one kilometer.

Three hundred and fifty years ago when men began first to think about the shape of the earth, on which it was their privilege to live, they called it a sphere, and they made rude little measurements on its great surface to ascertain its size. These measurements, as we know, at length after nearly two centuries, reached an extent and precision sufficient to prove that its surface was not spherical. Then the earth was assumed to be a spheroid of revolution, and with the lapse of time the discrepancies in the data, when compared on that hypothesis, seemed to also indicate that the assumption was incorrect. Granting that the earth is a sphere, there has been found the radius of one representing it more closely than any other sphere; granting that it is a spheroid there has been also found, from the best existing data combined in the best manner, the dimensions of one that represent it more closely than any other spheroid. But as further and more accurate data accumulate alterations in these elements are sure to follow. In our last lecture we saw that the radius of the mean sphere could only be found by first knowing the elliptical dimensions, and here it might, perhaps, be also thought that the best determination of the most probable spheroid would be facilitated by some knowledge of the theory of the size and shape of the earth considered under forms and laws more complex than those thus far discussed. In our next lecture, then, let us endeavor to give some account of the present state of scientific knowledge and opinion concerning the earth as an ellipsoid with three unequal axes, the earth as an ovaloid, and lastly, the earth as a geoid.

SANITARY ENGINEERING

By Captain DOUGLAS GALTON, F. R. S.

Read at the Sanitary Science Congress, at Croydon.

From "The Builder."

The President of the Congress, Dr. Richardson, has explained to you in his lucid address that the life of a man on this globe might reasonably be expected to extend far beyond that to which he now ordinarily attains, provided he were removed from all the conditions unfavorable to long life which encompass him. Of these conditions some are hereditary, some arise from habits, and are personal to the individual. But there is another large class of conditions which are the direct result of the circumstances to which man is exposed in consequence of living in communities. All living beings are in a continual condition of change, which results in their throwing off from the body matters which poison earth, air, and water unless space, time, and opportunity are afforded for the counteraction of these deleterious effects. Epidemic diseases are observed to occur in very different degrees of intensity at different periods, amongst groups of population exposed to certain unhealthy conditions. Sometimes they take the form of pestilences, and immediately afterwards, the conditions remaining the same, they subside and all but disappear, again to renew their ravages at some future period. A careful examination of their phenomena has led to the discovery that whilst we have no knowledge of the causes which made these epidemics break out at one time and not at another, there are certain well-defined conditions which influence most materially not only their actual intensity, but also their frequency. Thus, intermittent fever was observed to disappear from places which it formerly ravaged after drainage of the soil and improved cultivation. It was next discovered that by cleanliness, fresh air, and diminised crowding the worst forms of pestilential fever, which used to commit ravages similar to those of the plague, disappeared entirely from English jails. The breathing of foul air contaminated by the breath of other persons appears to be the special agent which predisposes people to consumption and diseases of that class. Zymotic diseases,—namely, fevers. diarrhœa, cholera, dysentery, &c., —are most intensively active where there

is overcrowding, and the repeated breathing of air already breathed, such air being further contaminated by moisture and exhalations from the skin. It is to the phisiologist and the chemist that we must look for the causes from which these baneful effects arise, and what are the conditions which should be altered to prevent or remove them. The engineer steps in after these causes have been pointed out, and it is for him to design the methods of prevention or removal. Five hundred years ago the population of the whole kingdom was only equal to the present population of the metropolis. When the first recorded census was taken in 1801, the population of England and Wales was less than 9,000,000.; it has now reached nearly 25,000,000. We are crowded together as we were never crowded before; our pursuits are more sedentary, our habits more luxurious. Houses increase in number, land is more valuable, the green fields more remote; our children are reared among bricks and paving-stones. It is daily becoming more and more impossible in the question of health for any one member of a community to separate his interest from that of his neighbors. If he places his house away from others, the air which he breathes may receive contamination from the neighboring district; the dirty water which he throws away may pollute the stream from which his neighbors draw their supply; and when a population congregates into towns the influence of the proceedings of each individual on his neighbor becomes strongly apparent. On these and similar grounds it is the interest of every person in a community that every other member of the community should live under conditions favorable to health. Each year, as the population increases and as dwellings multiply, so does the importance of promoting these conditions increase; and so long as preventible diseases exist throughout the country we must not delude ourselves with the idea that we have done more than touch the borders of sanitary improvement. Books inumerable have been written upon the question. Physiologists have invented every conceivable theory; patentees have invented every conceivable description of apparatus; engineers, architects, and builders, overwhelm you with professions of their knowledge of sanitary principles, and millions of money have been spent in furthering the schemes they have devised; and yet, in spite of all these efforts, there are few houses and very few towns where you would not easily detect some grievous sanitary blunders. I believe this to be due, in the first place, to the fact that the majority of men prefer anything to thinking for themselves. They like to obtain their knowledge as they do their hats—from a shop, ready made. In the second place, the sanitary education of the country has not been brought into a system. People seem to have thought that sanitary knowledge could be picked up anyhow. Yet the problems which the sanitary engineer and architect are called on to solve require for their solution a knowledge of the higher branches of physics, chemistry, geology, meteorology, and kindred sciences, and entail as close habits of observation as any other branch of the engineering profession. In the third place, it has always seemed to me that the system under which the Government advances money for sanitary works, whilst of great *primâ facie* advantage in one point of view, yet has its disadvantageous aspect. But it may be asked, what is sanitary knowledge? It is frequently assumed that drainage and water supply are the principal subjects which are embraced in the term; but these only make up a small part of the subject. At the present time there does not exist any treatise which brings to a focus the various problems of mechanical and physical science, upon which sanitary knowledge is based. The variety of these problems will be best illustrated by a few instances. A sanitarian tells us that health depends on pure air and pure water. If a site is to be selected, it requires a consideration of its position with respect to its surroundings. It requires a knowledge of the temperature of the air and of the soil; what are the prevailing winds; what is the amount and incidence of the rainfall; and what is the percolative capacity of the soil. The engineer cannot interfere with the general conditions of a climate, but he may produce important changes in the immediate surroundings of a locality; he may modify the condition and temperature of the soil; he may control atmospheric damp; he may arrange for the rapid removal of rainfall, or he

may cause the rainfall to be retained in the soil, to be given out gradually in springs, instead of passing away in torrents to flood the neighboring districts. In the Island of Ascension, the power of retention of water in the soil exercised by the planting of trees was exemplified. That island formed a convenient point for ships to call at for obtaining water on their way home from the East Indies. It was a barren rock, to which formerly the water had to be conveyed in ships. About fifty years ago trees were planted on the island. These have thriven, and now the rain which falls, instead of passing away at once into the atmosphere by evaporation, is retained in a sufficient quantity to enable the water to be collected for the supply of the ships which call at the island. The engineer may modify the incidence of disease. Algeria, perhaps, offers some of the best illustrations of the manner in which engineering operations have remedied the evils of the proximity of marshes. Bona stands on a hill overlooking the sea; a plain of a deep rich vegetable soil extends southward from it, but little raised above the sea level. The plain receives not only the rainfall which falls on its surface, but the water from adjacent mountains, and is consequently saturated with wet. The population living on or near this plain suffered intensely from fever; entire regiments were destroyed by death and disease. It was at last determined to drain the plain. The result of this work was an immediate reduction of the sick and death rate. Fondouc, in Algeria, is situated on sloping ground, immediately above the marshy plain of the mitidja; mountain ranges rise immediately behind it. It was first occupied in 1844, and in the succeeding year half the population was swept away by fevers and dysentery. During the first twenty years the mortality was 10 per cent. The surrounding marsh has since been drained and cultivated, and the mortality now is 20 per 1,000. Similar instances may be quoted from our own possessions in India. In the northern Doab districts in the northwest provinces of India the excessive fever mortality for which these districts were noted has been mitigated by extensive drainage works, by means of which the water which formerly stagnated in the land is now led away by continuously flowing streams.

When a site has been selected, it is necessary to consider the question of the subsoil. The air does not cease where the ground begins, but air permeates the ground and occupies every space not filled by solid matter or by water. Thus it is the same thing to build on a dry gravelly soil where the interstices between the stones are naturally somewhat large, as to build over a stratum of air. The air moves in and out of the soil in proportion to barometric pressure, and with reference to the wind. If there is much water in the soil, the air carries with it watery vapors, and is cold, and such a site is called damp. A site with a high-water level is, as a rule, more unhealthy than a site with a low-water level; but a site with a fluctuating water level is most unhealthy. The sanitary engineer can control the water level in the soil, or construct works to remedy the evils of a wet site. There is also a considerable quantity of carbonic acid in the soil. It varies at different depths; it has been found to vary greatly even in localities in close proximity. The processes going on in the soil in these several places are therefore probably very different, and each will have its influence on the ground air. One evil arising from a foul subsoil is very apparent. In cold weather the temperature of a house is warmer than that of the outer air. If a house is built on soil containing deleterious matters, the impure air will be drawn into the house by the action of the warm air of the house. The sanitary constructor takes measures to check the passage of air between the house and the ground under and around it. What can be more dangerous, what more wicked, than the everyday proceedings, in the metropolis and elsewhere, of those persons who purchase a building site, who extract from it the healthy clean gravel and sand which it contains, allow the hole to be filled up with rubbish, and then proceed to build upon it? When the site has been selected, the sanitary architect has to consider how he will distribute buildings over it. The deteriorating effect of residence in towns has been frequently noticed. It has been calculated that of the adult population of London, 53 per cent.; of that of Bir-

mingham, 49 per cent.; of that of Manchester, 50 per cent.; and of Liverpool, 62 per cent. were immigrants from the country settled in the town, and that the majority of the incomers were men and women in the prime of life. The mortality in these four towns averaged 26 per 1,000, against 19 per 1,000 in the adjacent country districts, the mortality of persons under the age of fifteen being 40.7 per 1,000 in these towns, against 22 per 1,000 in the country districts. When we consider the causes of low health in towns, it becomes apparent that the extraordinary degree of unhealthiness is unnecessary. The superior healthiness of the model lodging houses is due in a measure to the careful provision of sanitary arrangements, but principally to the fact that the numerous stories in these buildings, whilst affording accommodation for a dense population on a limited area, are provided with free through ventilation, and allow of ample space all round for the circulation of air, as well as to the fact that impurities are not allowed to be retained in the open area round them. The next step in knowledge of sanitary construction is to learn how to obtain pure air in a building. What is pure air? What are the impurities which make the air of a town so different from the fresh air of the country? The volume of sulphurous acid from coal thrown up by our fires into London air is enormous. A cubic yard of London air has been found to contain 19 grains of sulphurous acid. The street dust and mud are full of ammonia, from horse dung. The gases from the sewers pour into the town air. Our civilization compels us to live in houses, and to maintain a temperature different from that out of doors. What are the conditions as to change under which we exist out of doors? The movement of the air is stated in the Registrar-General's reports to be about twelve miles an hour on an average, or rather more than 17 feet per second. It will rarely be much below 6 feet per second. In a room the conditions are very different. In barracks, in a temperate climate, 600 cubic feet is the space allotted by regulation to each soldier; and when in hospital, from 1,000 to 2,500 cubic feet to each patient. If it were desired to supply in a room a volume of fresh air comparable with that supplied out of doors, it would be necessary to change the air of the room from once to five times in every minute, but this would be a practical impossibility; and even if it were possible, would entail conditions very disagreeable to the occupants. Hence, to maintain the comfort and temperature we desire indoors, we sacrifice purity of air. Therefore, however impure the outer air is, that of our houses is less pure; and it may be accepted as an axiom that by the best ventilating arrangements we can only get air of a certain standard of impurity, and that any ventilating arrangements are only makeshifs to assist in remedying the evils to which we are exposed from the necessity of obtaining an atmosphere in our houses different in temperature from that of the outer air. On the other hand, why should we not do our best to obtain as pure air as we can? It has been recently shown that the soot and many deleterious matters from smoke may be easily removed by passing the smoke through spray on its way to the chimney. This would remove much impurity from town air; but until such a system of purifying town air is adopted, we can improve the air in our houses by removing the suspended matter from the inflowing air by filtration. Moreover, these suspended matters exist in much smaller quantities at an altitude; at 100 feet they are greatly diminished, at 300 feet the air is comparatively pure. In Paris, the air for the Legislative Assembly is drawn down from a height of 100 feet, so as to be taken from a point above many of the impurities of the town atmosphere. That is a reasonable and sensible arrangement, and might be usefully adopted in public buildings in towns. In the Houses of Parliament, the so-called fresh air is taken from courtyards on the street level, from which horse traffic is not excluded. It may be summed up, that whatever the cubic space, the air in a confined space occupied by living beings may be assumed to attain a permanent degree of purity, or rather impurity. One of the chief difficulties of ventilation arises from the draughts occasioned thereby. Every one approves of ventilation in theory, but practically no one likes to perceive any movement of air. The open fire-place creates circulation of air in a room with closed doors

and windows. The air is drawn along the floor towards the grate; it is then warmed by the heat which pervades all objects near the fire, and part is carried up the chimney with the smoke, whilst the remainder, partly in consequence of the warmth it has acquired from the fire, and partly owing to the impetus created in its movement toward the fire, flows upwards towards the ceiling near the chimney-breast. It passes along the ceiling, and, as it cools in its progress towards the opposite wall, descends to the floor, to be again drawn towards the fireplace. Thus the open fire, whilst continually removing a certain quantity of air from the room, which must be replaced by fresh air, causes an efficient circulation of the air remaining in the room. Moreover, a room warmed by an open fire is pleasanter than a room warmed by hot-water pipes. A warm body radiates heat to a colder body near to it. The heat rays from a flame or from incandescent matter pass through the air without heating it; they warm the solid bodies upon which they impinge, and these warm the air. With complicated buildings, such as theatres, legislative assemblies, prisons, etc., the problems of ventilation are more difficult and intricate, but all are based on the same principles of the movement of air. Another group of questions relating to sanitary construction are: What are the best materials for the house, and the best distribution of those materials? How can the less pure air from the ground be prevented from entering the house through the basement? What is the effect of the porosity of materials on the health of the inmates of a house? What is the law which regulates the loss of heat through walls and windows, skylights and roofs? One instance of the sanitary importance of the quality of materials will suffice here. Dust and impurities adhere less to glass of a good quality than to glass of a bad quality. But there is one branch of work connected with water supply and drainage in which practical knowledge is especially necessary, and which has not been so prominently considered as it should be. I mean the details of the plumber's work, and the work connected with house-drains. However well you may design your house-drains, the whole of your design may be rendered nugatory by apparently trifling mistakes or carelessness in the details. Public attention has been so largely directed to water supply and drainage that I cannot refrain from offering a few remarks upon these subjects, which at the present time necessarily fill the public mind. We derive our whole water supply from rainfall. If it falls on an impervious surface, it runs off in rivers above ground; if it falls on a pervious surface, it runs off underground in rivers whose direction of flow will depend on the geological formation. However much our population may grow, we cannot, therefore, increase our supply; but we may store it and utilize it if we obtain a knowledge of where it falls and where it flows to. It is thus the function of the sanitary engineer to trace the course of these water supplies. But rain does not fall equally over the whole country. On the contrary, as has been so well shown by Mr. Symons, there is in some localities in England an enormous surplus, and in other localities a bare supply, and the incidence of these supplies has no reference to the spread of population over the country; thus it requires something beyond local organization to arrange for a distribution of the supply in accordance with the relative wants of the country. It is on these grounds essentially the duty of the Government to take up this question. The Government have taken into their hands the more thoeretical question as to when storms may be expected; but they have not taken in hand the question which has an enormously greater practical importance, viz., that of watching over our water supplies, although it is on the careful use of these that the health of the whole country depends. The first step towards obtaining a clear understanding of the question is to bring all the information on this subject to a focus.

At the present time there are certain important public departments, the information collected by which bears materially on the sanitary condition of the country; and yet these departments are scattered about indiscriminately, as if with the intention of preventing the information they already possess, and could so easily add to, from being brought to any useful focus. The departments to which I allude are,—first,

the Ordnance Survey; second, the Geological Survey; third, the Registrar-General's Department; and fourth, the Meteorological Office. The first step is to bring these departments under one general head, so that the information they can severally afford may be properly correlated; and the Local Government Board would seem to be the department under which they would most naturally fall. On the question of sewage, time would not allow me to enter; it is sufficient to say that this must remain always a problem for the sanitary engineer, because no one system of sewage could be adopted universally; the peculiarities of different localities require different methods of treatment. Where land at a reasonable price can be procured, with favorable natural gradients, with soil of a suitable quality and in a sufficient quantity, a sewage farm, if properly conducted, is apparently the best method of disposing of water-carried sewage. In the case of towns where land is not readily obtained at a moderate price, some of the processes, based upon subsidence, precipitation, or filtration, produce a sufficiently purified effluent for discharge, without injurious results, into watercourses and rivers, provided the volume of water into which it is discharged is of sufficient magnitude to effect a considerable dilution. But, as a rule, no profit can be derived at present from sewage utilization. My object in this *résumé* has been to endeavor to show how extensive is the field of knowledge which has to be traversed by those who undertake the duty of building healthy houses, and of watching over the arrangements for securing the health of towns. The acquisition of sanitary knowledge covers a vast area of ground, and requires special study. The universities of Oxford, Cambridge, and London instituted examinations in public health, but with little success; few candidates came forward, and indeed no candidates offered themselves for Oxford or London at the last examination. Until some means of obtaining the education can be afforded, it is of little avail to establish examinations, or to offer to give degrees. The Sanitary Institute, whose *raison d'être* is to promote sanitary progress, has from the first recognized the importance of developing sanitary education, and has now decided to come forward as its champion. With this object, the Sanitary Institute proposes to organize a course of lectures to be delivered in the practical branches of this question during the coming winter, and in this effort which they are about to make for the public good, the Council trust they will receive the support of all those interested in sanitary progress. There is, however, a further step required in order to produce throughout the country a due recognition of the importance of sanitary knowledge, and this step should be at once taken. The medical officers of health, who are the advisers of the local authorities on questions connected with public health, have obtained a title to their position in the medical profession, by virtue of certificates from qualified Boards of Examiners. But local surveyors, whose duty it is to advise local authorities on matters of sanitary construction, are not required to produce any such certificate of qualification. The summary of the conclusions to which I would lead you in this address are, therefore—1. That endeavors should be made to cause the adoption in educational establishments of courses of systematic education in sanitary science for those who undertake the business of sanitary construction. 2. That no person should be appointed to the office of surveyor of a Local Board or Corporation, without a certificate from some duly-qualified educational institution of proficiency in practical sanitary science.

A NEW bridge over the Burdekin river, Northern Queensland, on the road to Charters Towers, has just been completed, and is worthy of mention as being one of the largest in the colony; it is 1200 feet from end to end, with the exception of two spans over the waterway, which are 45 feet and 25 feet respectively; the whole of the bridge consists of 20 feet spans, the main girders and headstocks being of hard wood, 14×14, and the piles, which are concreted 4 feet into the rock, having a diameter of 17 inches at base. The work has been carried out by Messrs. Watson & Johnson, under the superintendence of Mr. M'Millan, the engineer for roads and bridges, Northern Division.

ON TOPOGRAPHICAL SURVEYING.

By GEO. J. SPECHT, C. E.

Written for VAN NOSTRAND'S MAGAZINE.

THE object of Topography is to determine the relative positions of points of the earth's surface, that can be referred without error to a tangent plane, and therefore independent of the sphericity of the globe.

The operations of a topographical survey, consequently, are two—namely, to first project a system of points upon such a tangent plane; and, secondly, to find the distances of the same above or below the plane; or, in other words, to measure the lengths of the projecting normals. The first process is ordinary surveying, the second, leveling.

The results of a topographical survey are laid down in a so-called topographical map, which is a representation or complete image of the ground on a reduced scale.

Topographical maps are of the greatest convenience in locating railroads or other roads, in planning irrigation works, draining works, in mining enterprises, in military operations, &c., &c. In a topographical map the configuration of the ground is reduced to an image, which represents to the eye a large area at one glance, which in nature could not be viewed but by many separate inspections; therefore, the judgment about the relation of the different parts of the work will be a clearer and more intelligent one. This refers especially to mining work, where very frequently the problem occurs, to strike a vein with a tunnel in a certain level. In this problem a correct topograghical map will often save the mining company several hundred feet of tunnel work, or in other words thousands of dollars.

One reason why topographical surveys are not oftener made, is certainly the slowness on one hand and the inaccuracy on the other hand of the old methods.

Two different methods have heretofore been employed; one has the great disadvantage of slowness, and the other that of being unreliable. The first is a combination of common surveying with leveling. Provided these two operations are carried out with all possible care, the work will be a very exact one; which, however, will partly be lost by the inaccuracy of the drawing. Therefore, in this method, the field-work is unnecessarily superior to the requirements of the case, as the reduced scale of a topographical map does not allow the representation of the smaller details. And as the topographical map is the first and direct object of a topographical survey, the latter ought not to be more exact than the scale of the map requires; for instance, if the map is made on a scale of 1.5000 ($1''=416.6'$), the distances on the map can be read or estimated with any certainty only within four feet. Consequently, the survey does not need be more detailed than to correspond to this limit. The second method is also a combination of common surveying with leveling, yet in a more hurried and therefore unreliable manner; it is on ground of a measured and leveled base to sketch the surroundings. As a matter of course the correctness of a topographical map, derived from such a survey, depends entirely on the ability of the topographer to estimate the relations between the different points. And as there are too many sources of error such topographical maps are but little value; they render good service in military reconnoissance, but hardly anywhere else.

Without going into the details of the old methods (which are shortly treated in Gillespie's Handbook), I shall proceed at once to give an account of the new method of topographical surveying. The word "new" is justified only in view of the two above-mentioned methods, as the one to be described has been known since 1852, when the Italian Professor and Officer of Artillery, Porro, of Milan, gave an account of this method *Annales des Ponts et Chaussées*, and when also the French engineer, Minot, published a treatise on this subject. The French and the Italians were the first who used it; then it came largely into use in Switzerland, where, in connection

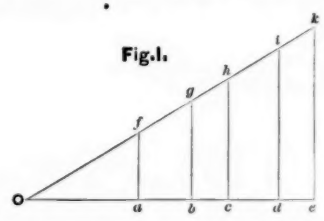
with the plane table, it was and still is used for the beautiful and masterly-executed topographical maps of Switzerland, in a scale of 1.50,000, with contour lines of 30 meters distance. Austria and Germany followed next, and are using it largely in railroads and similar enterprises. To-day it is used in those countries wherever any work of that kind is done; the Prussian General Staff employs it nearly exclusively. When and to what extent it was introduced in the United States is not known to the writer, but the note of A. S. Hardy, Professor of Civil Engineering in the Chandler Scientific School, in VAN NOSTRAND'S ENGINEERING MAGAZINE, Aug., 1877, indicates that this method was hardly known, for otherwise he would not have praised the old, old method, he mentions, as quite a new application of contour lines. The United States Coast Survey uses this new method extensively in connection with the plane table.

THE NEW METHOD

of topographical surveying consists in simultaneously obtaining the horizontal and vertical positions of a point; in other words, each point is determined by *one* operation in reference to its horizontal and vertical location. This is accomplished by the use of a transit with the so-called stadia wires and a vertical circle, and a leveling rod or so-called telemeter or stadia-rod.

Besides the ordinary horizontal and vertical cross hairs of the diaphragm of the telescope, two extra horizontal hairs are placed parallel with the center one, and equally distant on each side of it, which, if the telescope is sighted at a leveling rod, will inclose a part of this rod or stadia-rod, proportional to the distance from the instrument to the rod. By this arrangement we have obtained an angle of sight, which remains always constant. Supposing the eye to be in the point O (Fig. 1), the lines O e and

Fig. 1.



O k represent the lines of sight from the eye through the stadia-wires to the rod, which stands consecutively at $k\,e$, $i\,d$, $h\,c$, $g\,b$ and $f\,a$. According to a simple geometrical theorem we have the following proportion:

$$O\,a : O\,b : O\,c : O\,d : O\,e = a\,f : b\,g : c\,h : d\,i : e\,k,$$

which means that the reading of the rod placed on the different points a, b, c, d and e is proportional to the distances O a, O b, O c, O d and O e.

The system of lenses which constitute the telescope do not allow the use of this proportion directiy in stadia measurements, because distances must be counted from a point in front of the object glass at a distance equal to the focal length of that lens.

Fig. 2.

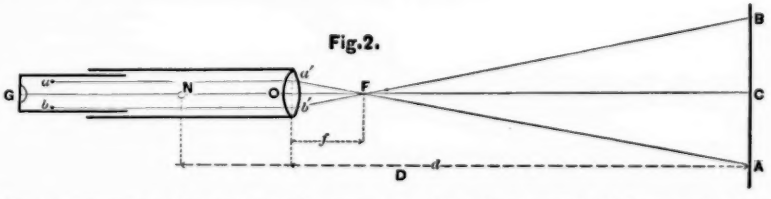


Fig. 2 represents the section of a common telescope with but two lenses, between which the diaphragm with the stadia-wires is placed.

We assume:

f = the focal distance of the object glass.
p = the distance of the stadia-wires a and b from each other.
d = The horizontal distance of the object glass to the stadia.
a = stadia reading (B A).
D = horizontal distance from middle of instrument to stadia

The telescope is leveled and sighted to a leveling or stadia rod, which is held vertically, hence at a right angle with

the line of sight. According to a principle of optics, rays parallel to the axis of the lens, meet after being refracted in the focus of the lens. Suppose the two stadia wires are the sources of those rays, we have, from the similarity of the two triangles, $a'\ b'$ F and F A B the proportion:

$$(d-f) : a = f : p.$$

The value of the quotient, $f : p$, is, or at least can be made, a constant one, which we will designate by the letter k; hence we have:

$$(d-f) = \text{F C} = k\ a.$$

In order to get the distance from the center of the instrument N, we have to add to the above value of F C yet the value c.

$$c = \text{O F} + \text{O M}.$$

O M is mostly equal to half the focal length of the object, hence we have

$$\text{C} = f + f_2 = 1.5\ f.$$

Therefore the formula for the distance of the stadia from the center of instrument, when that stadia is at right angles to the level line of sight, is:

(1) $$\text{D} = k.a + c.$$

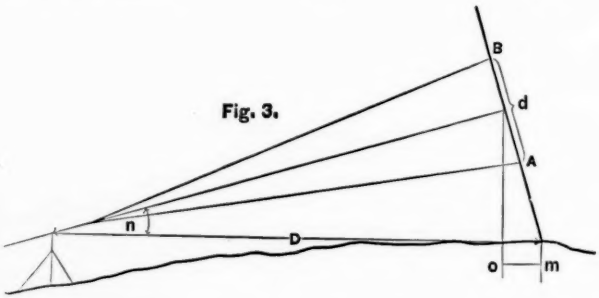


Fig. 3.

When the line of sight is not level, but the stadia held at right angle to it, the formula for the horizontal distance is:

(2) $$\text{D} = k.a.\cos n + c + om.$$

The member $\overline{om} = \frac{a}{2}\sin n$; for $a = 24'$, $n = 45°$ the value of $\overline{om}$ is but $8.4'$, and for $a = 10'$, $n = 10°$ it is $0.86'$; this shows that $\overline{om}$ in most cases may safely be omitted.

Some engineers let the rodman hold the staff perpendicular to the line of sight; they accomplish this by different devices, as, a telescope or a pair of sights attached at right angle to the staff. This method is not practicable, as it is very difficult, especially in long distances, and with vertical angles for the rodman to see the exact position of the telescopes, and furthermore, in some instances it is entirely impossible, when, for instance, the point to be ascertained is on a place where only the staff can stand, but where there is no room for the man. The only correct way to hold the staff is vertically.

In this case we have the following: (Fig. 4)

$$\text{MF} = c + \text{GF} = c + k.\text{C.D}$$

CD must be expressed by AB.

$$\text{AB} = a. \quad \text{AGB} = 2m.$$

$$\text{CD} = 2\text{GF}\tan.m.$$

By the similarity of the two triangles AGF and BGF, we have after some transformations

$$\text{AF} + \text{BF} = \text{GF}\sin m \left(\frac{1}{\cos(n+m)} + \frac{1}{\cos(n-m)}\right)$$

$$\text{GF} = \frac{\text{CD}}{2\tan m}, \quad \text{AF} + \text{BF} = a$$

$$a = \text{CD}.\ \frac{\cos m.\sin m[\cos(n-m) + \cos(n+m)]}{2\sin m.\cos(n+m)\cos(n-m)}$$

$$\text{CD} = a\frac{\cos^2 n\cos^2 m - \sin^2 n\sin^2 m}{\cos n\cos m}.$$

$$\text{MF} = c + \text{GF} = c + k.\text{CD}.\ \text{MF} = \frac{\text{D}'}{\cos n}$$

$$\frac{\text{D}}{\cos n} = c + k.a\ \frac{(\cos^2 n\cos^2 m - \sin^2 n\sin^2 m)}{\cos n\cos^2 m}$$

$$\text{D} = c.\cos n + a.k.\cos^2 n - a.k.\sin^2 n\tan^2 m.$$

The third member of this equation may safely be neglected, as it is very small even for long distances and large angles of elevation (for 1500′, $n=45°$ and $k=100$, it is but 0.07′). Therefore, the final formula for distances, with a stadia kept vertical, and with wires equidistant from the center wire, is the following:

(3) $\quad D=c.\cos n+a.k.\cos^2 n.$

The value of $c.\cos n$ is usually neglected, as it amounts to but 1 or 1.5 feet; it is exact enough to add always 1.25′ to the distance as derived from the formula

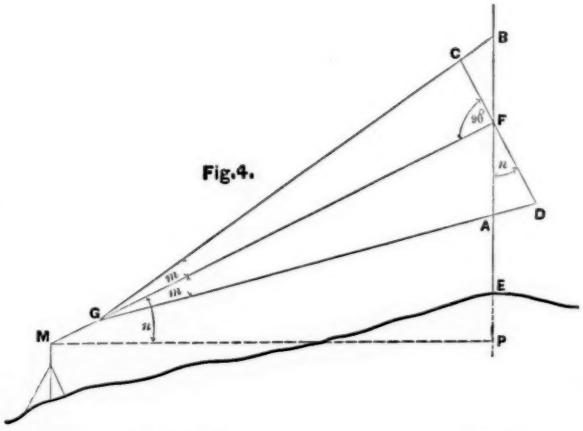
(3a) $\quad D=a.k.\cos^2 n$

without considering the different values of the angle n.

In order to make the subtraction of the readings of the upper and lower wire quickly, place one of the latter on the division of a whole foot and count the parts included between this and the other wire; this multiply mentally by 100 (the constant k) which gives the direct distance d'.

In cases where it is not possible to read with both stadia wires, it is the custom to use but one of them in connection with the center wire, and then to double the reading thus obtained. With very large vertical angles, this custom is not advisable, as is shown by the following theoretical investigation:

Fig. 4.



Take the same figure 4 as above

$$BF=\frac{BG\sin m}{\sin(90°+n)};\quad AF=\frac{AG\sin m}{\sin(90°-n)}$$

$$BF=\frac{GF.\sin m}{\sin(90°-m-n)};$$

$$AF=\frac{GF.\sin m}{\sin(90-m+n)}$$

$$\frac{BG\sin m}{\sin(90°+n)}=\frac{GF\sin m}{\sin[90°-(n+m)]}$$

$$\frac{BG}{\cos n}=\frac{GF}{\cos(n+m)};\quad BG=\frac{GF\cos n}{\cos(n+m)};$$

$$GA=\frac{GF\cos n}{\cos(n-m)}$$

$$BG:AG=\frac{GF\cos n}{\cos(n+m)}:\frac{GF\cos n}{\cos(n-m)}$$

$$BG:AG=\cos(n-m):\cos(n+m)$$

$$BF:(BF+AF)=\cos(n-m):[\cos(n-m)+\cos(n+m)]$$

$$AF:(BF+AF)=\cos(n+m):[\cos(n+m)+\cos(n-m)]$$

$$\frac{BF.2\cos n\cos m}{\cos n\cos m+\sin n\sin m}=\frac{AF.2\cos n\cos m}{\cos n\cos m-\sin n\sin m.}$$

$$\frac{BF\cos n\cos m}{\cos n\cos m}-\frac{BF\sin n\sin m}{\cos n\cos m}=\frac{AF\cos n\cos m}{\cos n\cos m}+\frac{AH\sin n\sin m}{\cos n\cos m}$$

$$BF(1-\tan n\tan m)=AF(1+\tan n\tan m)$$

$$BF=\frac{a}{2};\quad AF=\frac{a}{2}$$

Now if we multiply one of these values with 2, we see that the result is not equal to a, but equal to $a \pm a \tan n \tan m$; hence the distance D is either too long or too short by the amount of $a.k.\cos^2 \tan n \tan m$; for $a=15'$, $n=45°$ and $k=100$, the distance measured with both stadia wires is 749.7,' but as measured with only one stadia wire and the center wire, we have either 753.4′ or 746.0′, which is an error of 0.50%; for $a=15'$, $n=22°$ and $k=100$, we have correct distance=1289.1′, distance with one wire, either 1286.5′ or 1291.7′, which is an error of 0.25%.

To find the height of the point where the stadia stands, simultaneously with the distance, we have the following:

We assume, in reference to figure 4,

q=height of instrument point above datum.

MP=D=horizontal distance as derived from formula (3).

n=vertical angle.

h=FE=stadia reading of the center wire.

Q=height of stadia point above datum; it is,

$$Q=q+D\tan n-h.$$

The subtraction of h can be made directly by the instrument, by sighting with the center wire to that point of the rod, which is equal to the height of the telescope above the ground (which is in most cases=4.5′); q will be constant for one and the same instrument point; then the above formula:

$$Q=D\tan n;$$

this in connection with formula (3) gives

$$Q=c\sin n+a.k.\cos n.\sin n.$$

or
$$Q=c\sin n+a.k.\frac{\sin 2n}{2}$$

The first form of the equation can be neglected, when the vertical angle is not too large; hence the final formula for the height is

(5)
$$Q=\frac{a.k.\sin 2n}{2}$$

The position of the stadia must be strictly vertical.

Without giving here the theoretical investigation of the manner in which an inclination of the stadia towards or from the instrument affects the distance, I shall mention but the results of the investigation on this subject. The following table is calculated from a formula given by Professor Helmert, of the Royal Polytechnic School in Aachen (Germany):

$$D-D'=\pm\tfrac{1}{2}k\sin 2n\sin o\sqrt{2m^2+\frac{a^2}{2}},$$

where D is the reading at a stadia exactly vertical.

D′ is the reading at a stadia not vertical.

k=the constant, n=vertical angle, o=angle of inclination of the stadia when not held exactly vertical, m=height of the center wire, and a=stadia reading.

The table is calculated for $k=100$, $\sin o=0.01$, and for $m=1'$, 4.5′ and 10′.

	n.	$a=$ 2.0	3.0	4.0	5.0	6.0	8.0	10.0	12.0
10°	1.	0.34	0.43	0.54	0.62	0.76	0.99	1.22	1.46
	4.5.	1.10	1.12	1.18	1.24	1.30	1.42	1.62	1.89
	10.	2.42	2.43	2.46	2.48	2.51	2.59	2.70	2 80
20°	1.	0.64	0.32	1.01	1.18	1.43	1.88	2 32	2.76
	4.5	2.08	2.16	2.23	2.33	2.25	2 72	3.06	3.56
	10.	4.57	4.60	4.65	4.68	4.79	4 82	5.10	5.28
30°	1.	0.87	1.11	1.37	1.59	1.93	2.53	3.13	3.72
	4.5.	2.82	2.92	3.01	3.14	3 31	3.68	4.13	4.80
	10.	6.18	6.20	6.26	6.31	6.38	6.60	6.85	7.15
40°	1.	0.98	1.25	1.55	1.81	2.20	2.88	3.56	4.22
	4.5.	3.19	3.30	3.41	3.58	3.77	4.18	4.68	5.45
	10.	7.00	7.05	7.11	7.18	7.25	7.49	7.80	8.12

The error increases with the height of m.; in shorter distances the result is sevenfold better when the center wire is placed as low as one foot than it is at 10′; in longer distances this advantage is only double.

It is always better to place the center wire as low as possible. If the stadia is provided with a good circular level, the rodman ought to be able to hold it vertical within 500 seconds; that means, that the inclination of the stadia shall not be more than 0.023′ in a 10′ stadia, or 0.034′ in a stadia of 15′ length.

DETERMINATION OF THE TWO CONSTANT COEFFICIENTS t AND k.

Although the stadia wires are usually arranged so that the reading of one foot signifies a distance of 100 feet, I will explain here, how to determine the value of it for any case. Suppose the engineer goes to work without knowing his constant, and not having adjustable stadia wires. The operation then is as follows:

Measure off on a level ground a straight line of about 1000′ length; mark every 100′, place the instrument above the starting point, and let the rodman place his rod on each of the points measured off; note the reading of all three wires separately, repeat this operation four times; the telescope must be as level as the ground allows; measure the exact height of the instrument, *i. e.*, the height of the telescope axis above the ground. Then find the difference between upper (o) and middle (m) wire; between middle (m) and lower (n) wire, and between upper (o) and lower (n) wire, from the four different values for each difference, determine the average value; then solve the equation for the horizontal distance (1) $D=k.a.+c.$, with the different average values, and you find the value of k and c. In case the stadia wires should not be equidistant from the center wire, there will be three different constants, one for the use of the upper and middle, one for the use of the middle and lower, and one for the upper and lower wire. The following example, which occurred to me, will explain these rules: (the measures are meters, which, of course, makes no difference).

Number of Observations.	Distance Measured.	Stadia Readings.			Differences.			Angle of Elevation.	Height of Instrument.
		$o.$	$m.$	$u.$	$o-m.$	$m-u.$	$o-u.$		
	Meters.								
	25	1.503	1.300	1.117	0.203	0.183	0.386	0° 32′	
	50	1.503	1.100	0.727	0.403	0.373	0.776		
1.	75	1.810	1.200	0.640	0.610	0.560	1.170	1° 0′	
	100	1.915	1.100	0.355	0.815	0.745	1.560		
	115	1.940	1.000	0.140	0.940	0.860	1.800	1° 2′	1.318
	115	1.940	1.000	0.140	0.940	0.860	1.800		
	100	1.915	1.100	0.350	0.815	0.750	1.565		
2.	75	1.810	1.200	0.640	0.610	0.560	1.170		
	50	1.507	1.100	0.730	0.407	0.370	0.777		
	25	1.700	1.500	1.316	0.200	0.184	0.384		
	25	1.502	1.300	1.116	0.202	0.184	0.386		
	50	1.504	1.100	0.730	0.404	0.370	0.774		
3.	75	1.812	1.200	0.642	0.612	0.558	1.170		
	100	1.915	1.100	0.355	0.815	0.745	1.560		
	115	1.940	1.000	0.140	0.940	0.860	1.800		1.318
	115	1.937	1.000	0.140	0.937	0.860	1.797		
	100	1.915	1.100	0.355	0.815	0.745	1.560		
4.	75	1.810	1.200	0.640	0.610	0.560	1.170		
	50	1.505	1.100	0.728	0.405	0.372	0.777		
	25	1.701	1.500	1.315	0.201	0.185	0.386		

The base was 115m long.

Out of these observations, we derive the following means:

Distances.	Differences.		
	o—m.	*m—u.*	*o—u.*
24	0.201	0.184	0.385
50	0.405	0.371	0.776
75	0.610	0.560	1.170
100	0.815	0.746	1.561
115	0.939	0.860	1.799

The different values of these differences, applied to the formula for horizontal distances, (the angle of elevation is so small that it need not be considered),

$$D = k.a + c,$$

we have the following fifteen equations:

Equations for (*o—m*)

$$\text{I.}\begin{cases} 25^{m} = 0.201\ k + c. \\ 50^{m} = 0.405\ k + c. \\ 75^{m} = 0.610\ k + c. \\ 100^{m} = 0.815\ k + c. \\ 115^{m} = 0.939\ k + c. \end{cases}$$

Equations for (*m—n*)

$$\text{II.}\begin{cases} 25^{m} = 0.184\ k + c'. \\ 50^{m} = 0.371\ k + c'. \\ 75^{m} = 0.560\ k + c'. \\ 100^{m} = 0.746\ k + c'. \\ 115^{m} = 0.860\ k + c'. \end{cases}$$

Equations for (*o—n*)

$$\text{III.}\begin{cases} 25^{m} = 0.385\ k + c''. \\ 50^{m} = 0.776\ k + c''. \\ 75^{m} = 1.170\ k + c''. \\ 100^{m} = 1.561\ k + c''. \\ 115^{m} = 1.799\ k + c''. \end{cases}$$

By solving these equations, we obtain the following average values for the constants k and c, k' and c', k'' and c''.

For the group I we have;

$$k = 122.30,\ c = 0.40.$$

For group II:

$$k = 133.30,\ c' = 0.45.$$

For group III:

$$k'' = 63.70,\ c'' = 0.50.$$

This example shows one of the most unfavorable cases, as we obtain three different values for each of the two constants, because the stadia wires are not equi-distant from the center-wire. If the stadia wires are adjustable, the engineer has it in his power to adjust them so that the constant $k = 100$, and $k_2 = 200$, which he accomplishes by actual trial along a carefully measured straight and level line.

The constant C, which is one and a half times the total length of the object-glass can be found closely enough for this purpose by focussing the telescope for a sight of average distance, and then measuring from the outside of the object-glass to the capstan-head-screws of the cross-hairs. This constant must be added to every stadia sight; it may be neglected for longer distances.

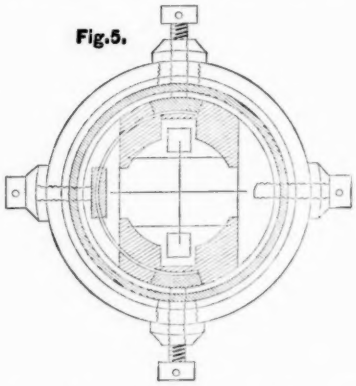
THE INSTRUMENTS

used in this method are the following.

1, a transit or theodolite, which in general construction is like the common one; the only new features of it are the stadia wires and the vertical arc.

The diaphragm carrying the cross wires has two sides, which can be moved by small capstan heads crews, and on each end of which one stadia wire is fastened;

Fig.5.



an inserted spring makes their position more steady. By means of those screws the distance of the stadia wires from the centre wire, and from each other can be adjusted at will.

For stadia measurement it is far preferable to use a telescope with inverting eyepiece as they allow a longer distance to be read; the little inconvenience at first of seeing the objects inverted, will very soon be overcome, and the engineer will gladly adopt it, because it enlarges the range of his work so advantageously. Light and magnifying power are the

essential points for a telescope used in stadia measurements, more than in any other branch of surveying. Therefore, the telescope ought to have none but the two-lens negative eye-piece, which inverts the objects. The so called Kellner's orthoscopic eye-piece should be used (Fig. 6); it is completely achromatic,

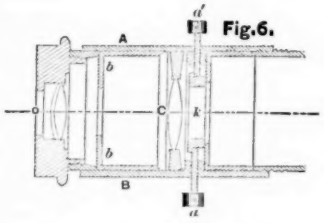


Fig.6.

and has the great advantage, which no other eye-piece has, of an actually flat field and a straight flat image of any object, correct in perspective, distinct in its whole extent. It consists of three lenses, the bi-convex collective lens C, the flatter curve of which is towards the object-glass, and the achromatic lens O, which is composed of two lenses, similar to the achromatic object-glass. The diaphragm *b*, *b*, is a further peculiarity of this eye-piece Messrs. Buff & Berger in Boston use such eye-pieces in their instruments.

The vertical arc must be larger than usual, so as to allow of a vernier reading of at most one minute. In order to make no mistakes in reading the vertical angle, whether it be an angle of elevation or depression, the numbering of the vertical arc must be so arranged that the zero point of the arc corresponds with the zero of the vernier, when the telescope is level, and the numbers go from 0° to 360°. By this arrangement the observer knows at once whether the angle is an angle of depression or one of elevation, without using the signs of minus or plus. The now very often preferred arrangement of making the vertical arc fixed, and the vernier movable with the telescope is far inferior to the fixed vernier and the movable arc

A transit or theodolite fitted out in this way is called a tachometer, which means "quick-measurer," and hence this method is "tachometric."

The next instrument essential to the topographical survey is the rod or stadia rod or telemeter; this is a self-reading leveling rod, with a graduation fit to be read at a long distance. A good rod must have the following qualities:

1. It must be light and handy for transportation.

2. The graduation must be distinct and visible at long distances; it is not to be closer than one-tenth of a foot, as otherwise the reading would become confusing for longer distances. Experience teaches that smaller subdivisions can more exactly be estimated than read by a direct division.

3. It must have a good and reliable arrangement to enable the rodman to keep it in the required position.

It is advantageous to add a target to the rod, which is used but for the most important points, especially at new stations for the instrument.

The rod consists of two or more parts, which are either entirely separated during the transport and put together by means of screws or otherwise, when used, or they are connected with each other by hinges, or are made to slide in or along each other. I am using one which consists of three separate pieces, each 5 feet long and of a cross section, as shown in figure 7; the ends are pro-

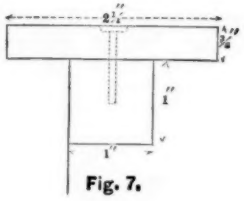


Fig. 7.

tected by iron shoes; the pieces are joined by screws. On the back is a circular level. (Fig. 8).

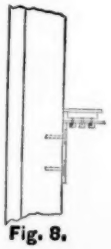
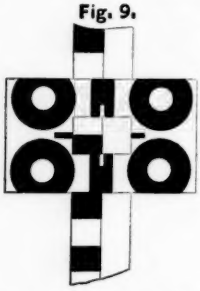


Fig. 8.

As to the pointing of the rod, the two styles shown in Figs. 10 and 11 are very practical. The alternative position of the feet makes the reading a great deal easier and the whole graduation much more distinct. Fig. 11 represents a so-called "combination rod," which can serve as a common leveling rod by means of the small subdivisions. The largest I use is represented in Fig. 9; it slides

Fig. 9.



along the small edges of the rod; the circles do not touch each other, but are yet so close that the exact center of the target can be estimated very exactly; it has no vernier, which, however, could easily be attached.

In order to save a second target, the

Fig. 10.

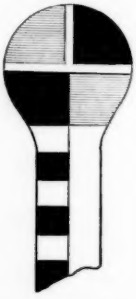
Fig. 11.

end of the stadia is shaped as shown in Fig. 12, so making it a stationary target. The colors to be used are best either black and white, or red and white; red has the advantage that the cross wires can be distinguished on it, which they cannot on a black division. The white ought to have a light yellow shade.

These are the instruments used in the stadia method of topographical surveying. Now, I shall describe the mode and manner of working; I have to make the distinction between work done with the tachometer and work done with the plane-table.

For railroad surveys, with the tachometer, the field party must consist of two engineers, one assistant, two rodmen, who serve at the same time as flagmen and eventually as chainmen, one or two axmen. The engineer in charge of the

Fig. 12.



party, after a general reconnoissance of the country, selects the points upon which the rodmen have to place their stadia; he makes sketches of the general lay of the country in his field book, and numbers the points in his book as taken by the stadia. Goldschmidt's Aneroid will be a good companion for him.

The purpose of the work and the scale of the topographical map—if such is to be made—determines the number of points to be taken. In railroad work it will generally suffice to take as many points as will enable the engineer to make an intelligent estimate of the amount of earthwork to be done, and to make accordingly changes of the line in his map without going anew into the field. The engineer in charge of the instrument places the same over the initial point, which is chosen so that as large a

field as possible can be seen from it, without regarding whether it is in the probable future line. One of the rodmen takes all points to the left, the other all those to the right of the instrument; it is a matter of course that the rodmen must be quite intelligent and well instructed. The assistant has charge of the field book and writes down the readings which the engineer calls out. He also gives the signals to the rodmen as directed by the engineer, and, if time permits, makes the necessary calculations. Some engineers do away with this assistant, but the employment of one expedites the work to a great extent.

A good and distinct system of signals between engineer and rodmen is very essential. In order to avoid confusion, each tenth point of each rodman is indicated by them by a signal; also roads, trails, creeks, and similar objects must be marked in a similar manner. Where only one rodman is employed, a whistle or little trumpet will suffice; when two or more rodmen are at work each must have his own style of signal.

Two, or at the most three, rodmen are plenty to keep the engineer and one assistant busy.

In order to avoid mistakes the rodman, who is not sighted at, but has already arrived at his new point, should uot put up his staff in correct position before he hears the signal, which allows the other one to move, but must keep it in an inclined position, being ready to place it correctly as soon as required. A well understood code of signals is a very important point.

After a sufficient number of points has been taken, one of the rodmen goes to the engineer in charge, who selects the next point for the instrument, which he must select in reference to a good foresight and in understanding with the engineer on the instrument, as the latter must give the correct grade by setting his telescope at a vertical angle corresponding to the grade the road shall have. Here the rodman uses the target. After such a point has been selected, the instrument is removed to it. Meanwhile, the second rodman has returned to the former instrument point and placed his rod with the target on it; after the engineer has taken his back sight to this point and checked by it his first stadia reading, the rodman comes to him and they proceed as before.

That disturbances in the position of the telescope may be detected and accordingly taken into account, it is advisable to sight at the beginning of the work at a fixed and well marked point, as a house corner or any other well defined object, and to sight at it again at the end of the work before removing the instrument to the next point. This is a check which ought never to be neglected.

In order to determine the distance between the two instrument points as exactly as possible, and to free the same of all instrumental errors, the readings for those points must be done in both positions of the telescope. The horizontal angles for those points must be read not only with the needle, but also with both verniers; this also ought to be done for the determination of houses, bridges, or other important points. If the instrument has a repeating circle, it is advantageous to place the zero point of the verniers on the zero point of the limb, when the telescope is pointed to the preceding standpoint.

An other precaution, to guard against errors in the distances, is, to determine two or three points in the line about half way between the two stand points, which are sighted at from either one. By this, two measurements of the distance are obtained, each independent of the other, thus giving a very good check

The method as described above, of course, allows many variations; each engineer will soon form his own style of working; so, for instance, if good, reliable and intelligent rodmen are to be had, one engineer for the whole party will be sufficient; the progress perhaps will be a little slower, and then besides, the above method has the advantage, that the engineer in charge has an opportunity to make himself thoroughly acquainted with the ground, to make valuable sketches and notes.

The proceeding in a topographical survey for other purposes than railroads, must be a little different, according to the space to be embraced. For railroad survey, only, but a narrow strip of land on both sides of the line is required; but for mining, irrigating and similar purposes the field to be surveyed is of larger extent. Therefore, the following

proceeding is advisable. First select a sufficient number of points all over the country to be surveyed, which shall be the future points of the instrument. Select those points so, that at least two other points can be sighted at from each, and that as large an area of ground can be surveyed from it as possible. Secure them with good, solid monuments; then make a triangulation of those points (which operation sometimes may be combined with the actual topographical survey), and determine their heights by a careful leveling. After this proceed with the topographical survey as described before.

This method, of course, is comparatively slow, but gives most satisfactory results, as the work is constantly checked by the triangulation and leveling, which was done independently of the topographical survey; it is the best method for all mining and irrigation enterprises and, generally speaking, for all undertakings, where permanency of the works is contemplated, and where during the course of the survey some engineering work is in progress. Here, those points, trigonometrically determined and well served by good monuments, will always serve as reliable points of reference and check; they are of permanent value.

Sometimes it will suffice to determine only a limited number of trigonometrical points, but well selected, so that they can be seen from a great many points in the field to be surveyed; then the instrument points are determined in reference to them. This method will prove most convenient with the plane table, as the points then can be determined by the three-point problem.

Although most engineers will make their own blanks of field book, to suit their views and customs, I give here a blank, which has served a good purpose.

No. of instrument, point and height of telescope above datum.	No. of the point sighted at	Vernier reading on the horizontal limb.		Vertical.	Stadia reading of			Difference.	Reduced distance.	Height of point above or below telescope axis.	Height of point above datum.	Remarks.
		Vernier I. also Needle reading.	Vernier II.	Angle	Middle wire. (m)	Upper wire. (o)	Lower wire. (u)	$o-u$		$\pm$		

The stadia method, heretofore described in connection with the tachometer, is still more useful with a plane-table.

The alidade is profitably provided with a so-called parallel ruler, which contributes a great deal to the quickness of the work, and—although not correct from a theoretical point of view—is quite exact enough for the work usually required.

The compass box must be a rectangular one to allow a line to be drawn along its edge. By this, the North line is directly drawn upon the paper. After a sheet is filled, or the work finished, it is advisable to draw the scale on the sheet itself, so that the changes of the paper shall not introduce error.

For all further particulars about the plane table, I refer to the book published by the U. S. Coast Survey on this subject, and, for the adjustments of the instruments, I refer to the catalogues of the different makers.

I will now refer to those topographical maps in which the topography is represented by means of constant lines. To use the words of Professor L. M. Haupt: "This method of representing topography is vastly superior to any other, as it exhibits exactly the slope of any portion of the ground, gives the elevation of the base of any object within the tract, enables one to make vertical sections in any direction with accuracy from the plot, and so locate roads, paths or other

features upon a given grade or at any desired elevation, and furnishes the means of calculating the contents of irregular solids with great precision."

A contour line is a line which connects all points of one and the same height with each other; therefore, their nearness or distance on the maps indicate the steepness or gentleness of the slopes; the nearer together, the steeper, and the more distant from each other, the gentler is the slope of the country represented.

Although not exactly belonging to the subject of this treatise, I will say a few words about railroad locating generally. These are suggested by some remarks of Arthur M. Wellington, C. E., in the introduction to his highly interesting book, "The Economic Theory of Location of Railroads." He says, page 18, and following:

"Another inevitable consequence of such general neglect is that this intricate science of design has been degraded in popular esteem, and even in the minds of engineers, who ought to know better. In former times the ablest engineers gave personal and unremitting attention to the work of location, but we have changed all that at the present day. As soon as a young man has acquired some facility in transit work, and has some glimmering notion that curves and grades are very objectionable evils—or are *not* very objectionable evils, depending on whom he "ran transit" for—he is forthwith a locating engineer, and he is such in fact in so far as this, that further practice will teach him nothing. For after making one or two surveys he will have mastered the mechanical process of handling a party, and begin to look down on the work of location—because he knows nothing about it. His work is the dead corpse of location, beginning and ending in the transit. If he is a rising man he will soon find some other young man to take his place in the field, and do the *really important* work, and very probably begin that vicious system of office-location from contour maps which has ruined the alignment of so many railways. Now, all this is especially calamitous, for it is almost a certainty that any one who has not a thorough *theoretical*, as well as practical knowledge of location, will fail entirely to catch the governing features of the region traversed, and find the line which has probably been lying there since time began. The instances are almost innumerable where young men—and old men—of this class have run over and under and across a line of the highest operating value, and turned in a costly and miserable line at last. And the contour-map system does not help this evil even in the hands of a thoroughly capable engineer; for the contour map is simply a device for doing ill in the office, the simplest part of the work, viz.: the first approximation to the adjustment of the line in detail; and its most effectual office is, to deaden the perceptive faculties of the engineer in charge of the party and transform him into a mere machine. Of what value is a contour map of an ill-judged line? The truly difficult part of location is the selection of the general route and the final ultimate perfection of its adjustment in detail; and the engineer who can do *this* work well will thank no one for the rude assistance of a contour-map location, made without the detailed familiarity with the ground which is gained by tramping over it. In fact, he will approximate to the detailed alignment quite as well and as rapidly without any such assistance, simply by feeling his way upon the ground, profile in hand, and his party behind him, and guided by a few notes from a rough plot. Nor will such an engineer, if he have a true feeling for the dignity and importance of his work, be content with making some contour-map guesses to be tested by less skilled subordinates. If he is to interfere in any way and his judgment have any value on paper, it is worth more upon the ground; and there is where he ought to be. He will detect more possibilities while sitting on the fence in apparent idleness than by the longest study of maps, and however long his experience or brilliant his ability, he can at no time in his professional career have more important financial interests depending on a chance inspiration. It should be more generally recognized that the place for the ablest engineers, which money will command, is not in the office or on construction, but in the field at the head of the locating party.

"A large part of this evil is not the fault of engineers, but is due to the fact that the financial loss from bad location

is too distant and indirect to excite an amateur's apprehension, and every officer of a railway, from the president down, is an amateur engineer—having all the amateur's fondness for 'meddling and muddling' in *unimportant* matters, and all the amateur's reluctance to recognize anything as important which he does not himself understand. The fatuity displayed by the average railway official in this way quite passeth understanding. He will pay lavishly for his attorney's skill in trickery; he will even pay repectably for the manager's skill in dealing with men and with things; but he will neither pay for nor believe in that vastly more needed skill of the engineer, in dealing with abstract physical and mechanical laws, and in determining the financial meaning of their relationship to involved and contradictory facts. For this work ne neither seeks for nor will he tolerate anything more than a hand to execute; and the law of supply and demand gives him just what he asks for. Especially is this true in location. On the great majority of railways surveys are entrusted without the slightest uneasiness to the first graduate of the transit who comes to hand; but when he has *completed* his work, and construction is to begin, *then* we may behold an extraordinary and amusing spectacle. Then we may see half a dozen business men, who probably show some common sense in their own affairs, scouring the country with a lantern to find a constructing engineer of the greatest possible ability at the smallest possible salary—to do what? To pay over the money which is *already spent;* to pare and shave at the cost of work which might have been avoided altogether; to *build* the complicated mechanism for which they have just permitted Thomas, Richard and Henry to make designs and working drawings. This kind of folly has its root in some of the deepest foibles of human nature, and it will probably never be done with altogether; but it is to be hoped that railway companies may more generally appreciate the fact that their road is built and equipped in the brain of their locating engineer—if he has any; and that if his work be ill done, all the engineers in Christendom have done little to remedy his errors, though they execute his folly for half its proper cost. The truth is, in fact, that ordinary constructive engineering is a much lower branch of professional labor, and makes far less drafts on those qualities of mind which make the engineer. But massive piles of dirt and stone and iron are visible evidences of power which impress the imagination of the wayfaring man as equal evidences of skill, and hence it is not wonderful that the ability of engineers is more generally estimated by the grandeur of the works they have executed than by those which they have avoided."

I quote these words in their entirety, first, because they partly meet with my most hearty consent, and, second, because they are directly contrary to my views and opinions, and, third, because they contain many things which ought to be generally known and considered by everybody interested in this question. I fully agree with Mr. A. Wellington, when he says that the *location* of a railroad is the most important work relating to railroad affairs, which must be constantly and personally attended to by the chief engineer himself, and must not be left to an inferior and inexperienced "transit man." And again, I fully agree with him that the locating engineer and the constructing and building engineer ought to be one and the same person, a person who has experience not only in those two branches of railroad engineering, but also in the operating of a railroad. As Mr. Wellington has so thoroughly and admirably shown in his book, the knowledge of the financial effect of a grade or a curve is the most important in the location of a railroad; and this knowledge can only be derived from actual and personal experience; their effects can be investigated intelligently and successfully only by a man who has a thorough knowledge of the constructing of the road, and why it is so constructed, and not otherwise. The head of operation of a railroad ought to be an engineer, who is not—as he nearly invariably is, I am sorry to say—hampered in his doings by a board of directors, who profess to know everything about managing a railroad, but who, in fact, do know but how to buy and sell sugar and coffee. (That there are some brilliant exceptions in respect to these boards of directors ought not to be the

cause to make them a rule). This, of course, involves a higher standard of engineers than we usually have; it involves the raising of the engineer profession to the importance it deserves, and finally must and will have. As at present the engineers are situated, it is perfectly shameful; it is inconsistent with the purpose he is here for, and is damaging to the welfare of the enterprise he is engaged for. Here is not the place to treat about this question to any extent, but it is one of vitality to the engineers.

As to Mr. Wellington's views on the contour-plan question, I have to say the following: If the system of contour maps is carried on and used as it apparently was when Mr. Wellington became acquainted with it, it certainly is a "vicious system." But, if carried out in the right way, it is certainly the most beneficial system that can be invented. To bring about such an effect, the following condition is essential: the person who makes, or personally and actually superintends, the location of a railroad, must be the same who locates the line in the contour maps; by the survey and the tramping over the ground, he requires a thorough knowledge of it, and has made himself entirely familiar with all its qualities; the contour maps, then, is for him a fully intelligible image of the ground, and as it represents a larger field to his eye than he can overlook with one sight in the field, he can judge more intelligently about the relations of distant parts to each other; he can at once decide the effect a change at any point will have on any other point. With what right Mr. Wellington says, "for the contour map is simply a device for doing ill in the office, the simplest part of the work, viz., the first approximation to the adjustment of the line in detail, and its most effectual office is to deaden the perceptive faculties of the engineer in charge of the party, and transform him into a mere machine," I cannot explain otherwise, than that he has not had much experience with the system, and that he did not get on the right side of it. The contour map is just like a relievo of the ground, and enables the engineer to work in it as the sculptor works in his clay; he can mould in it as the circumstances require it. The engineer, who has a thorough knowledge of the ground, and locates a railroad on a contour map, in comparison to the engineer who locates the railroad but in the field, where his field of view is but limited, is like the general, who leads a battle from an elevated standpoint, to the officer who has charge of only one wing of the army, being situated so that his eyes can embrace but the small space occupied by his own regiment or battalion. Now, as a change of any part of a railroad line—which is a continuous uninterrupted line—affects always some other part of it, it is necessary to investigate at once the effects the change will have on the whole line. If there is no contour map, it is necessary to locate a shorter or longer part of the line anew, which again may prove not advantageous, so necessitating a third location of this part of the road. This is the cause of great delay and expense. But when there is a contour map, such expenses can be avoided. The engineer, who is familiar with the ground, locates in his contour map the new line, calculates by means of the same map the amount of earthwork to be done, finds perhaps that this new line is not an improvement, tries another one, calculates again its cost, and so on until he finally finds the best line. And this is all done with but a slight expense. This, of course, always supposes that the contour map is a correct one, and not on too small a scale. (1.1000 or 1.500 are the most practicable scales). I will give shortly the account of a location with this system, as actually carried out by myself. I shall omit the account of the survey for the contour map, and shall suppose the latter to have been made. It was constructed in a scale of 1.500, a scale which allows the smallest unevenness, which would influence the location of railroad, to be expressed. The base line, on which the survey was founded, was approximately the future railroad line, but, of course, without curves. The first thing was to lay down the curves in the map, which were not staked out in the field, and to calculate the grade for about every 100 feet, then the so-called "intersecting curve" was constructed in the plan. This is the line, where a plane laid through the imaginary height of railroad

intersects the ground; it represents to the eye at one glance approximately the points, where too much cutting or too much filling would be necessitated, hence, where the line should be changed. Where this was the case, the line was moved until it laid in about the center of the "intersecting curve," *i. e.*, so that on each side of the line about an equal part of the curve was lying. This could be found without much calculation of cross sections. When the probable best line was found, the cross sections were constructed and calculated, which were easily and quickly constructed from the map by assistants, the one reading the distances and heights from the contour map, and the other drawing the cross section on profile paper equally divided each way. The area of the sections and also the cubic content were found by means of the planimeter, the latter in this way: Draw in the center of the paper a horizontal line which shall be the axis of the ordinates, set off on it all distances of the cross sections, and erect in these points verticals; where cutting is, draw verticals above the line, and where filling, below; then set off on each of those verticals the respective area of the cross section (the areas represented by length) and connect the end points of these verticals with each other, by a continual and smooth curve; the scale for the areas, of course, may be another one than that of the distances. Then find the areas of the figures enclosed by those curves and the horizontal center line with the planimeter. These areas will be the cubic content.

These few remarks will suffice to show how useful the contour maps may be when rightly used. I shall now describe how the topographical map is made from the data derived by the tachometer. The first thing to be done is to lay down the base line, or the line which connects the different instrument points with each other, which is done by the common method of latitude and departure, or sines and cosines. The intermediate points are laid down from each point by means of a protractor, which is divided into half degrees, and has on its straight edge two scales with a common zero point, which lies in the vertical drawn through the line of 90°. The graduation of the protractor is numbered twice, once from 0° to 180°, and then from 180° to 360°. The numbers run in the direction opposite to that of the instrument. The center point of the protractor is secured by a little horn plate, with a hole in its center; this is brought over the station point and a needle put into it, so that the protractor can be turned around it as a center point. One person reads the angles and distances from the field notes (which have been completed first in regard to reduced distance and height), the other person first places the protractor so that the zero line coincides with the north line, then turns the same as much as the angle requires, and marks the distances by means of the scale and fine needle on the map. The scales of the protractor, of course, must be the scales of the map. After the point is marked down, the height, as given from the field notes, is written near it. After all points are laid down in this manner, the contour lines must be drawn, which can be done in many different ways; it should be done by the engineer, who has charge of the field party, because he is the most familiar with the ground.

According to my experience, the best and quickest way is the following: use paper which is divided into squares, with sides of one-tenth of an inch length; then draw a profile through the two points between which the contour lines shall be constructed. The intersections of the horizontal lines with this line will be the points of the contours, and their distance from the center vertical line will be their horizontal distance.

The curves must be drawn with great care and full understanding of the ground; their construction is a problem of descriptive geometry, and requires great attention.

The points, actually obtained, should not be rubbed out after the contour lines have been constructed, but they must be preserved by a little black point, and the number indicating the height also in black. The contour lines should be drawn either with burnt sienna or with green; their numbers must be written on them at many points with the same color. Each fifth or tenth curve should be drawn in a little different manner from the other—for instance, dotted or stronger; this contributes a great deal to

the distinctness of the plan. All other details of the map should be marked black with the conventional topographical signs. The steepness of the ground, the scale of the map and the purpose of the work, determines in which heights the contour lines shall be drawn, whether for each foot or for each 3, 5, 10, 20 or 100 feet.

THE SLIDE RULE.

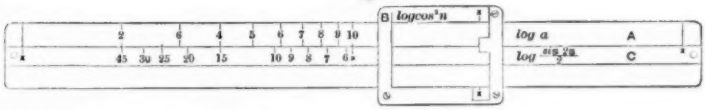
It would be very tedious and slow, to calculate for each point the respective values according to the formula, as above given for the distances and heights. There are several tables published, which, with two arguments, give the respective values, (one is calculated by Alfred Noble and W. T. Casgrain, assistants U. S. Engineer office at Milwaukee), but the best device is a slide rule, which was first constructed by the Swiss Engineer Eschman, and afterwards improved by Professor Wild in Zurich.

I suppose, the theory and use of the common slide rule is known to the reader, (if not, I refer him to my pamphlet on this subject).

The slide rule as used in topographical surveys consists of a ruler A, a slide C, and a coulisse B.

The ruler has on its upper part four equal scales, each of which is a logarithmic scale of the common numbers. The scales commence with the number one, as the logarithm of $1=0$; the space between the numbers 1 and 2 is divided into 50 parts; that between 2 and 3, and 3 and 4 and 5 into 20 parts each, and that between 5 and 6, 6 and 7, 7 and 8, 8 and

Fig. 13.



9, 9 and 10, (or 1 of the following scale) into 10 parts each; hence the scales read as follows, commencing on the left 1, 1.02, 1.04, 1.06, ... 1.98; 2. 2.05. 2.10. . . . . 4.95; 5.00, 5.10, 5.20, 5.30, ... 9.90, 10.00. With increasing numbers the divisions become smaller, as differences between their logarithms become smaller. The values between the divisions must be estimated. The numbers indicated on the scales can stand either for the numbers themselves, or they may stand for any decimal value of them; thus, 1 stands for 1, 10, 100, 1000 etc., or 0.1, 0.01, 0.001, 0.0001 etc.; 2 stands for 2.20, 2.00, 2.000 etc., or 0.2, 0.02, 0.002 0.0002 etc. It is a matter of course, that the value given to one number of the scale influences the whole. It is practicable to give the first scales to the left, the value of from 10 to 100, and the second of from 100 to 1000.

On the coulisse B. there is the scale of log. cos. n^2 (see formula 3); this scale counts from the right to the left, as cos.^{2} n is always smaller than one, the irlogirithms therefore negative? The space from

0 to 10 is equal to the log. cos^2 10°,

that from

0 to 20 is equal to the log. cos^2 20°,
0 to 40 is equal to the log. cos^2 40°.

The first part of the space 0 to 10 stands for log. cos^2 4°, the second for log. cos^2 6°, and the third for log. cos^2 8°. The part between 10 and 20 stand for each two degrees, and those between 20 and 40 for each degree.

This scale on coulisse B in connection with the scales on A, are used for calculating the distance, it is;
log. d=log. $(a \cos^2 n)$=log. a+log. cos^2 n log. a (the logarithm of the stadia reading) is given on scale A, log. cos$_2$ n on scale B.

Place the point 0 of the coulisse B above the stadia reading on the scale A, (or above the stadia reading plus 1.5 p), and look, which number in the latter scale stands below the vertical angle of scale B; this will be the horizontal distance.

Example: stadia reading $a=2.48'$, $p=12''$, $n=5°20'$; place 0 of scale B above 249.6 $(a\ k+c)$ of scale A, and read under 5° 20′ the reduced distance estimated to 248′; if the angle were

10°, D would be =242′,
20°, D " =221′,
30°, D " =187.7′,
40°, D " =146.4′, etc.

From this instance, it can be seen that for smaller angles the result, as given by the slide rule, is not as exact as for greater angles, but still exact enough for practical purposes.

On the slide C there is the scale of $\log \frac{\sin^2 n}{2}$ [see formula (5)]. It commences with the value for 35 minutes at the right hand end, and the graduations from 1 to 3 stands for each two minutes,

3— 5 " " 5 "
5—10 " " 10 "
10—20 " " 20 "
20—30 " " 30 "
30—40 " " 1° "

from 40°—45° there are no smaller subdivisions.

Formula (5) is

$$\log Q = \log ak + \log \frac{\sin 2n}{2};$$

therefore, place the line for the vertical angle on the scale C under the stadia reading of scale A_3 or A_4 and find above the left index (the line with the star) the height. In the case the left index falls beyond the scale, the center index or the right one can be used, but it must be considered that the center one gives ten times, and the right one hundred times the reading of the left index.

For the number of places of the height, we have the following rule: If the height be found in the same scale as the distance (or the value ak) is taken and the left index be used, the height has as many places as the distance; but if, in the same case the right index be used, it has two places less than the distance, and if the center index is used it has one place less than the distance; if the height be found in the proceeding scale and with the left index, it has one place less, and if in the same case the center index be used it has two places less, and if the height be found in the following scale with the right index, it has one place less, and if with the centre index it has just as much as the distance. In the following table z stands for the number of places of (ak):

Scale in which height is found.	Which index used.	Number of places of height.	$a\ k$	n	Q.
Same as distance.....	left	z	400	18°	118. 8′
" "	center	z—1	2400	5°	208. 0′
" "	right	z—2	2400	37′ 48″	26.16′
Proceeding.....	left	z—1	900	54′	14.06′
"	center	z—2	1750	2° 42′	82. 5′
Following	center	z	34.7	27°	14.05′
"	right	z—1	9	54′	0.141′

For smaller angles than 35 minutes the angle must be multiplied (perhaps by 10), and the result divided by the same number, which safely can be done, as for small angles the sine is nearly equal to the arc. If we had, for instance, $n=0°6′$, we would take $6\times10=60′$ or 1°, and place this angle below the stadia reading and divide then the result by 10. Example: $a=3.45$, $n=20′$; place the angle $10+20′=3°20′$ below 345, find

$$Q=\frac{20.00}{10}=2.00$$

(the exact result is 2.05).

On the lower edge of the slide rule, there is yet another scale, which is used for the reduction on account of refraction and curvature of the earth in greatly extended topographical surveys. For this scale, the lowest index, which corresponds with the others, is to be used in this way: Place the index of the coulisse B over the distance in scale A and find the correction under the lowest index on the scale of the lower index. These corrections are in the metric system. For instance:

D=500m, Correction=0.017m,
D=1000m, " =0.068m,
D=1500m, " =0.16m,
D=2000m, " =0.26m,

etc., which correction is to be subtracted from heights.

PNEUMATIC FOUNDATIONS.

Description of an Improved Closing Port, for the Discharge in Lock.

By A. HEINERCHEIDT.

Translated from "Annales des Ponts et Chaussées" for Van Nostrand's Magazine.

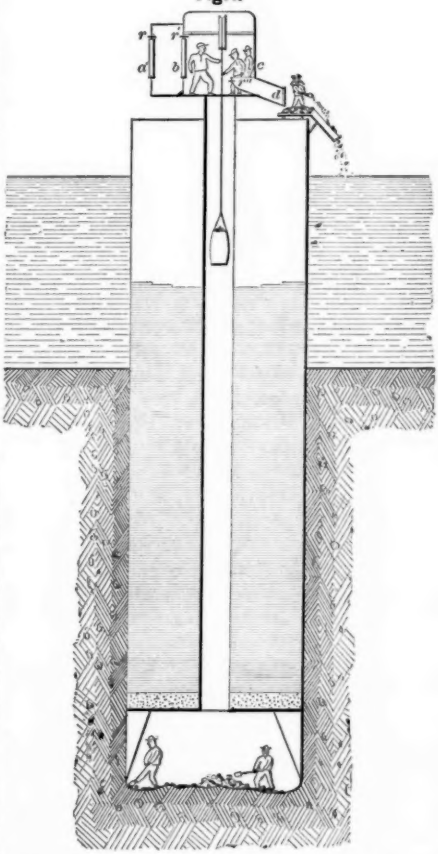
Foundations for abutments or piers which are constructed by aid of compressed air, generally employ a cylindrical caisson of iron, divided into two unequal parts by a horizontal partition; the upper part, which is the larger, is the caisson proper. It is a coffer dam, within which the masonry is built in the open air. The lower part, which is filled with compressed air, and within which the excavation is carried on, is called the *working chamber*. It is furnished with one or two shafts made of boiler iron, which are surmounted with an iron chamber called the air chamber. Adjoining this is the "equilibrium" chamber, or air lock, through which workmen and materials must enter. A pipe from the compressing engine furnishes the air chamber with compressed air. The air chamber and air lock are generally located above the highest level of the water, in order to insure the escape of workmen in case of accident to the dams above.

Figure 1 exhibits the relative position of the various parts.

The outlets to the air chambers—the air lock and the chutes—are furnished with two ports to be opened sucessively. The ports *a* and *b* of the air lock open towards the interior, so that the air pressure tends to keep them closed. To open either of them, it is necessary to equalize the pressure upon its opposite sides by means of the cocks *r* or *r'*. There is thus no danger of the port opening suddenly.

On the other hand the *discharge lock* is furnished with a port *d*, which of necessity opens outwards. Normally the port *c* is open, and the chute or lock is charged from within. When it is filled, the port *c* is closed, and a workman on the outside in charge of the port *d* is notified by a convenient signal. The outer port is then opened, and the charge removed. Then follows the closing of *d* and the opening of a cock *r''* which puts the discharge lock in communication with the air chamber. Equilibrium being thus established between the two sides of the port *c* it is reopened, and the charging is again resumed.

Fig. I.



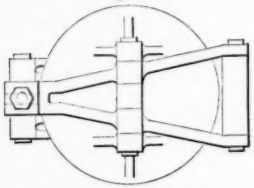
There is a constant source of danger in this system. Suppose there is a pressure of two atmospheres in the interior; then the pressure upon the port *d* tending to force it open is about twenty thousand kilograms to each square meter.

Any mistake on the part of the workman who has charge of the exterior port, whereby *d* is opened while *c* is also open would result in serious disaster to the workmen within.

In order to prevent such a catastrophe the following plan has been devised by the writer. It is designed to prevent absolutely, the opening of the exterior port until the interior one is completely closed.

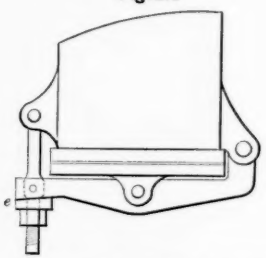
Fig. 2 represents the exterior port *d*.

Fig. 2.*a*



It is a cast iron disk suspended at the middle upon a shaft, which latter also is made to pass through two iron ribs, which cross the disk to unite in a fork at one edge, and diverging from this point terminate on the other side of the disk in a hinge point, working about an arbor fixed to the side of the chute. A third arbor also attached to the chute on the

Fig. 2.*b*



opposite side supports a rod, which passes through the forked rib, and is secured by nut and washer as shown in Fig. 2. When this screw is tightened, an equal pressure is exerted on the entire circumference of the seat of the disk. By employing rubber, an air tight joint is secured.

Thus far the description applies to the system in general. The modifications introduced by the writer are as follows:

The fork which receives the screw rod is constructed with a sloped bearing for the washer, as shown at *e*; the washer being also made to fit its seat. This secures the port against being thrown open from any pressure from within; also against too sudden opening by ordinary means. Several turns of the nut are required to allow a very small opening of the port. The workman, therefore, employs less force, and is relieved from some of the precautions employed before. A hole is made through both branches of the fork, and through the screw rod. Through this hole is passed a vertical rod, to the upper end of which is attached a bent lever. To the other arm of the bent lever is connected a horizontal rod. This latter passes through stuffing boxes into the air chamber, so as to be controlled from within. (Fig. 3.)

The working is easily understood. When the outer is closed, it is necessary before opening it to raise the vertical rod. This cannot be done unless the inner part is entirely closed.

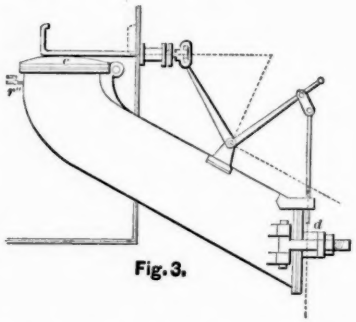


Fig. 3.

This device has been lately employed upon two air locks at Boom, for sinking pneumatic foundations for a bridge over the Rupel.

Two different plans were employed by reason of the different situations of the chutes in the two locks, but the principle is the same in both. The entire apparatus is light, not cumbrous; the time of working it is only the time required to raise the hand, and the security is absolute, as the reader is probably convinced by the above explanation.

The apparatus has been in use for two months, to the entire satisfaction of employees, and especially of workmen employed within the air chamber.

THE ACOUSTICAL IMPROVEMENT OF LARGE HALLS.

From "Engineering."

It is of course well known that the proportions of a room, as well as the character of the surface and contour of its walls and ceiling, exercise an all-important influence on its acoustical properties, and that even when every care has been taken in the designing of a concert hall or opera house to proportion the relative dimensions of its parts, as far as present knowledge of the subject can suggest, so as to obtain good acoustical results, it too often follows that the desired end remains to a great extent a matter of chance, and it is a curious fact that two buildings built upon the same model, and of identical proportions, often have totally different acoustical properties, and that a building may have its acoustics altogether altered for better or for worse, as the case may be, by the addition of decoration in the form of mouldings, cornices, curtains, and banners, and it has recently been pointed out by Dr. C. W. Siemens, F.R.S., that even the lighting of the gas in large buildings, such as the Albert Hall, by producing laminæ of heated air, can materially affect the acoustic conditions of the structure. It is obvious, therefore, that any contrivance which would enable the designer of a building intended for music or for public speaking, to insure against acoustical defects in his structure, or which would improve its capacity for the distribution of sound in the auditorium, would prove of the highest value to engineers, architects, builders, and contractors, as well as by all interested in the building, renting, or using of such places of public resort, and there have from time to time appeared schemes of one sort or another having the attainment of those very desirable objects in view.

The acoustic defects of large buildings are brought about by one or more of the following acoustic phenomena, and in some cases by all combined. (1) Dispersion, by which in large and lofty buildings, such as many of the magnificent Gothic cathedrals, the greater part of the sound waves produced by the human voice are free to wander away through great distances, until they expend themselves among the arches and galleries of the roof, and in the cavernous recesses of the chapels and transepts, leaving but a small proportion to reach the ears of the people in the body of the hall. (2) Resonance, by which discordant reverberations are produced, commencing nearly simultaneously with the note or sound by which they were originally induced, but continuing for some time after the original sound has ceased, and, therefore, interfering with the notes that follow. This is a common defect of domed and vaulted buildings, and the phenomenon may be observed in empty houses, and very often in tunnels in which it is combined with reflection or echo, with which it must not be confounded, although the two are seldom, if ever, found apart. Resonance is chiefly attributable to the sympathetic vibration of the air held within the vaults of the roof, or within a dome or gallery set up whenever a note is sounded whose period of vibration corresponds with that of the space in which the resonance is produced. But what is perhaps the most serious cause of defect in moderate-sized buildings is (3) the acoustical phenomenon of reflection or echo. It is by acoustical reflection that the sound waves traveling away from the speaker in all directions are arrested in their course by walls, ceilings, arches, and other reflecting surfaces, and are thereby prevented from exhausting themselves in space by being turned back in directions determined by the nature of the reflecting surfaces, and their positions with regard to the original source of sound; and were it not for the comparatively slow speed with which sonorous vibrations travel, reflecting surfaces would improve and intensify the original sound in both large and small buildings, much in the same way as a number of mirrors in a room improves its illumination by reflecting back a large proportion of the light which would otherwise be dispersed or absorbed.

It is generally considered that the quickest speed of talking which can be articulated clearly and heard distinctly,

is five syllables per second, and and as the velocity of sound is only 1125 ft. per second, it follows that in the time which elapses in quick talking between the articulation of one syllable and that of the next, the same sound could travel 225 ft., so that if a reflecting surface be 112½ ft., distant the reflection or echo of the first syllable should be heard at the moment the second syllable was being articulated, and would therefore clash with it as would the second with the third, and so on, and if there were other reflecting surfaces at distances two, three, and four times the distance of the first, their reflections or echoes would interfere with the second, third, and fourth syllable respectively from the first spoken syllable, and this clashing or interference of sounds, so destructive to the audibility of a speaker, is almost more serious for a singer, as notes are introduced at the wrong time, giving rise to discords and false combinations, and producing what has been called a "wooliness of outline" to the music which is being performed. Reflecting surfaces in close proximity to the source of sound improve and strengthen it as a reflector behind a source of light intensifies its front beams; it is only when the distance of the reflecting surface from the source of sound is such that the time occupied by a sound wave in traversing that distance and returning again occupies, say, the fifth of a second of time or more, that the reflection becomes an echo and is injurious to the acoustical properties of the building. In fact the difference between what is called a useful reflection and an injurious echo is merely one of distance. The common sounding board above a pulpit—which in this country is too often a disfigurement and an outrage upon architectural taste, and in Belgium and some other Continental cathedrals is made an exquisite piece of æsthetic ornament—is an instance of the use of a re-reflecting surface close to the source of sound not only for directing the sound waves on the audience, but for shielding them from two of the evils to which we have just alluded, namely, dispersion and echo. If sounding boards of the same angular dimensions with respect to the speaker were placed at distances from him greater than 112 ft. they would do nothing but harm, injuring by so many more sources of echo the acoustics of the structure in which they were fixed. Closely allied to and associated with the phenomena of reflection and echo is that of (4) interference, whereby sound waves are neutralized or intensified, according as the return or reflected waves meet others advancing in such a manner as to destroy or to coincide with them respectively; in other words, if they meet crest to trough or crest to crest, the former producing more or less a silencing of the sound and the latter an augmentation of it; and as these silencings and augmentations, from the very varied wave lengths of the sounds constituting either musical compositions or articulate speech, are altogether promiscuous in their occurence, it follows that audition is, by the phenomenon of interference, confused to a very serious extent. There is one more source of acoustical defect in large rooms, and that is (5) sympathetic vibration of sonorous bodies within it; this phenomenon is closely related to that of resonance mentioned above, but it differs from it in the manner in which it is produced. It is well known that a piano or a harp placed in a room in which a concert is being performed, although not being played upon, gives out a large proportion of the music being performed, and a person sitting near it can hear the music coming from it, as if some ethereal hand were playing upon it with the lightest possible touch. This very interesting effect is nothing more than the taking up by each string the vibrations of the air surrounding it which were thrown into tremor by notes emitted by other instruments whose period bore a harmonious relation to that of the string so affected. But it is not only strings that are so influenced—metal plates of various sizes and thicknesses, membranes such as a drumhead or a tambourine all are influenced by sympathetic vibration, and give out corresponding notes. It must be familiar to many persons that even a common hat held in the hand in the presence of loud music is thrown into a state of vibration when certain notes are sounded, which vibration is distinctly sensible as a tremor to the hand holding it, and we may say generally that anything capable of being thrown into vibration with sufficient rapidity to constitute a sound may be thrown into sympathetic vibration by corresponding sounds pro-

duced with sufficient force in their neighborhood.

We think we may safely say that all the above phenomena, with the exception perhaps of the first, *i.e.*, dispersion are with respect to their acoustic influence upon a building either decidedly useful, harmless, or positively detrimental, according as the distance of the disturbing body from the source of sound be small or great. Thus the cavity of the human mouth, as well as the important parts of most musical instruments, are resonators, which not only greatly improve the sound, but to which their quality, value, and character are chiefly due. Again, reflectors, such as pulpit sounding-boards and walls in close proximity to the speaker or singer, augment and intensify the effect as a mirror augments a light, and to the resonance and sympathetic vibration of solid bodies is due the reinforcement and enrichment of sound produced by instrumental sounding boards, such as that of a pianoforte, or those of other stringed instruments, such as the violin, violoncello, and double bass, and of which no more striking illustration can be given than the familiar one of placing the stem of a vibrating tuning-fork against a resonating body, such as a table or hollow wooden box.

Mr. Engert's invention is the utilization of the phenomenon of the sympathetic vibration of metallic plates placed in the neighborhood of the performers for taking up the notes as they are sounded, and giving them out again so as to mingle their synchronous sound-waves with those produced by the orig inal notes, and thus to intensify them and give them more body. With this object he places behind and about the platform a number of sets of sheets of steel of various thicknesses and areas, suspended to framework and attached to one another by spiral springs, so that they are free to move within certain limits in every direction, and being of very different thicknesses and size, each plate can pick out, as it were, its own set of notes which it reinforces, and those notes by which any particular plate is uninfluenced are taken up by other and different sized plates, whose periods of vibration correspond to a different set of sounds. At a trial concert, recently, Mr. Engert had placed behind the performers five sets of suspended steel plates, one set being at the back center of the platform, and the others being in two pairs, one on each side of the center, the whole being arranged more or less in an arc of a circle embracing the platform; and in front of the platform in the middle were three smaller sets of plates, behind which and close to them was placed the pianoforte. Each set consisted of five steel plates of different sizes, suspended in a vertical position parallel to one another, about an inch apart, by spiral springs, and having a second set of spiral springs which acted as distance pieces between them. The five sets at the back of the platform were enclosed in flat vertical cases, the fronts of which consisted of a set of louvre boards, which could all be opened or shut together exactly like the opening or closing apparatus of the swell of an organ, and by closing any one set of louvres that particular set of plates could, for experimental purposes, be thrown out of use, and with a similar object the smaller sets in the front of the platform were provided with curtains which could all be simultaneously drawn aside or closed up by means of strings.

During the performance of the concert there was unfortunately but one opportunity of testing the effect of the music, first with the apparatus in use, and then with the louvres and curtains closed up, and this was afforded by one of Signor Foli's songs being "encored" and repeated, the apparatus being in use during the first performance, but shut off during the repetition. That there was a difference between the two, no one with any pretence to a discriminating ear could be insensible, but we venture to think that the question whether the one was an improvement on the other or not was a matter purely of imagination, and from the opinions of others with whom we compared notes, we think that if a poll had been called of the impressions of those present as to whether the apparatus improved the effect or not the ayes would have been about equal to the noes. It is only fair, however, to state that it was announced by the inventor that the apparatus was far from being in good order, and in fact that some of the suspension wires had been broken alto-

gether through not being of sufficient strength to support the weight of the plates. We must confess that we do not see the applicability on any extended scale of such a system to the improvement of large halls, for the reason cited above, namely, that sympathetic vibrations, reflections, and resonances in order to be of any use for the improvement of sound must be close to its source, and therefore the amount of apparatus for the production of such phenomena must be very limited, and can in large buildings bear but an insignificant proportion to the size of the chamber, and to the many sources of defect which vastness of size introduces. We can readily believe that if the velocity of sound were equal to that of light, the multiplication of sets of Mr. Engert's vibrating plates placed all over and above the interior of a building, in the roof and around the galleries, might greatly augment and perhaps improve the sound, but as it takes a decidedly appreciable time for a sound to travel a distance which can lie within a moderately sized concert hall, we cannot but think that every set of apparatus placed within the building, except in the immediate vicinity of the platform, would add to the discordant reverberation, add to the echoes produced, and would in short be a remedy far worse than the disease it is intended to cure. Passing from general principles to matters of detail, we fail to see the advantage of mounting the plates upon springs; if we understand the phenomena correctly we are under the impression that the sort of vibration of the plates which is desired is a mebranous one, and not a bodily swing of the whole plate as a mass, which could hardly be rapid enough, or be in a condition to be imparted to the air so as to reproduce a musical note, and if this view of the case be the correct one, the plates might be rigidly fixed by their upper edges, or even all round, like the head of a drum, and their membranous vibration would not thereby be destroyed, but rather improved.

We are the more sorry to take this view of Mr. Engert's invention (to which the name Orpheophone might not be inaptly applied) from the fact that we understand it is the result of an experimental research extending over more than forty years; it may be, however, that we have not properly appreciated the reasoning by which he was led to his conclusions, or by which he anticipates being able by his invention to impart the most admirable acoustical properties to buildings of the worst acoustical construction. If we have misunderstood him we shall be only too glad to rectify the error by affording him an opportunity for the explanation of his undoubtedly ingenious apparatus.

THE FUTURE OF PORTLAND CEMENT

From "The Building News."

The manufacture of Portland Cement is at the present time passing through a crisis in its history. The inventions of Messrs. Goreham, Johnson and Michele have rendered unnecessary nearly half the plant formerly required, and works of the type in common use only a few years back will soon have become obsolete. Thus by the use of a minimum quantity of water and the employment of mill-stones for reducing the mixture of chalk and clay to a fine state of subdivision, as specified by Mr. Goreham, the "backs," covering a large area of ground, can be wholly done away with; and the mode of employing tunnels or chambers attached to the kilns, patented by Mr. I. C. Johnson, obviates entirely the necessity for coke-ovens, drying-floors, and some of the most costly and troublesome of the processes which have until recently been considered indispensable to the manufacture.

Nor is it merely in the processes used in the production of the cement that important changes are impending; the whole system of testing the cement will be likely, sooner or later, to be modified, and already in Germany it has been decided to abandon the present unsatisfactory plan of testing the neat cement, and to introduce one standard system

throughout the entire country—of employing for this purpose test-briquettes made from a mixture of cement and sand. One important fact, which must not be lost sight of, is the great reduction in price which has been already established by the simplifications introduced into the manufacture.

At the present time there can be but little doubt that in London it would be almost as cheap to use Portland cement mortar as to employ that made from the grey chalk limes now in almost general use in the Metropolitan district. It would be extremely difficult to persuade architects, engineers, and builders that such is the case; and we shall perhaps be thought rather over-sanguine in making such an assertion; but we are convinced that the time is rapidly approaching when Portland-cement mixtures will drive common lime mortar out of the field. Let us glance at the relative prices of cement and lime mortar, assuming that the cost of mixing them per yard of sand is the same in each case, and taking it at 2s., though in reality it is far more difficult to slake, and thoroughly mix lump-lime and sand than to make a mortar from Portland cement. 1st. As concerns prices: Portland cement is sold by the manufacturer by the ton of 2,240 lbs. The retailer, for the purposes of the London trade, puts up ten sacks each of 200 lbs. net, and sends out 20 "centals" of 100 lbs. each as a ton of cement, looking upon the remaining 240 lbs. as part of his profit.

Our advice, therefore, to large consumers, is to buy by the ton, not by the ten sacks.

The manufacturer, however good and perfect he may make his cement, finds that at the present prices it does not pay him to sell all his cement in what we term a "potential" condition; neither do any of the existing tests necessitate that he should do so; he, therefore, sends out a mixture of from 80 to 90 per cent. of Portland cement, and from 10 to 20 per cent. of "core," or hard particles, which certainly have no beneficial action, and may even be productive of serious injury to the consumer. If, as manufacturers assert, the present competition in the cement trade renders unavoidable this slovenly mode of grinding, or rather this neglect of sifting, it would be far preferable to permit Portland cement makers to add, to sifted cement, from 10 to 15 per cent. of fine grained sand, pulverized quartz, or slag, and to sell such a mixture as "adulterated cement."

By a strange anomaly, writers upon the subject, and even some experimenters, have made use of the argument that because, under certain conditions, a heavy cement (with 15 per cent. of residue, when passed through a sieve of 1,600 meshes to the square inch) will give better results when *tested neat*, if this residue is left in, than if only the fine particles are tested, therefore there is no object in the removal of the core; forgetting entirely that in practice such cement is not *used neat*, and that under a sand-test, with two or three parts of sand, this apparent advantage in the presence of the coarse particles at once vanishes. Another very singular fact is that in nearly all sieve-tests which have hitherto been suggested, a minimum residue with a certain sized mesh is propounded. Now if there is to be any good in the sieve test at all, and we hold this to be the most important of all tests with Portland cement, the entire absence of core with a sieve of a certain named number of meshes must be insisted upon. The sieve test should read: "The whole of the cement must be so ground as to pass through a sieve containing $40 \times 40 = 1{,}600$ meshes to the square inch, without any residue." It is curious how wrongly manufacturers regard this question of sifting. We were talking quite recently with a prominent cement maker on this subject, and he said: "If my cement had to be reduced to such a pitch of fineness, I should have to give up the business, as I should never get through the grinding." We asked him if he could give us even the roughest estimate of what ths extra cost might be, and he replied, "Half as much again as at present." On checking some of the cement as it ran from the hopper of the millstone, with a sieve of the size named, there was found to be a residue of $12\frac{1}{2}$ per cent. of core. When we pointed out that the total extra cost could not possibly exceed the expense of re-grinding this percentage of his present output, plus the cost of sifting, and raising the core back again into the stones—the expense of the two latter operations being

admitted to be almost inappreciable, he said he had never considered it in this light, but had thought of the power and labor necessary to grind *all his cement* fine enough to go through such a mesh at a single operation!

This is rather a long digression from the subject of the cost of cement; but it has been necessary, in order to prove that nearly all the cement in the market is degraded to the extent of nearly 20 per cent. by inert and unprofitable ingredients. As a forcible illustration of this, we once pointed out to an engineer who had been sending 10,000 tons of Portland cement to some large works in Russia, and who told us that the cost of transport exactly doubled the prime cost of the cement: "You have expended about £3,000 out of the £20,000 in sending grit to Russia, and this you might have saved by having all the cement sifted in this country before it was put into casks."

The cost of Portland cement, bought by the ton, and specified as capable of undergoing the usual tests, was, for a large work on the South Coast, recently quoted at 31s. 9d. This would imply a price in the London district of about 30s. per ton of 20 bushels at 112lbs. each, or, say, 31s. 6d. per cubic yard of 21 bushels. Taking sand at 4s. per cube yard, and a mixture of 5 yards of sand to 1 yard of cement, which, with sifted cement, gives a very excellent mortar; we get for 31s. 6d. + 20s. + 10s. for mixing, 5½ yards of cement mortar at a cost of 11s per cubic yard.

Gray lime is still sold in London, to the great advantage of the dealer, by the cubic yard, which is a survival of the obsolete "hundred," as we pointed out in a former article; but, without attempting to show what is obtained for a yard, we will ask our readers to assume that a cubic yard of gray lime, containing 21 imperial bushels, which we require for comparison with Portland, may be supplied for 10s. With this quantity, whatever specifications may have to say upon the subject, we have found, from careful observation, that the "intelligent Irishman" who makes the mortar uses two yards of river sand, or 2½ yards of pit sand (say the latter, to make out as good a case for lime as possible), and he obtains only, at best, 2½ yards of lime mortar for 10s. + 10s., and 5s. for mixing, or 10s. per cube yard, as against 11s. for Portland cement mortar. The former being a very poor and miserable imitation of the result obtained from the use of cement, which we trust soon to see taking its proper place as a London building material. It is true that this calculation implies an actual cubic yard of *pure* Portland cement, and one of freshly-burned lump lime, and both at prices rather below those to which we are accustomed. It is also true that lime could be sold much cheaper, and that Portland cement has perhaps been forced down to its lowest paying price. Still, with a difference of only 10 per cent, in the cost of the mortar, there should be no hesitation in the choice of which to use. The reduction in the cost of making Portland by the modern process, in the one item of fuel alone, shows a saving of 50 per cent.; the amount of coke used being stated for all purposes at from 8 cwt. to 10 cwt. per ton of finished cement.

We wish to say a few words, in conclusion, on the German system of testing a sand mixture in lieu of the neat cement. As we have stated on previous occasions, the existing plan of insisting on a cement of a given weight per imperial bushel is, when unchecked by the sieve, a direct incentive to imperfect grinding; as it is far easier to prepare a cement with 20 per cent. of coarse particles, weighing 118 lbs. per bushel, than one much more finely ground and deprived of its coarse particles, which would weigh only 110 lbs. Many engineers have been accustomed to regard cements ranging from 112 lbs. to 120 lbs. per bushel as superior to those weighing under 112 lbs.; it is, however, impossible to form any opinion on this point unless the fineness of the particles had been ascertained. The experiments of Mr. Colson bearing on this subject, published in the *Transactions* of the Institution of Civil Engineers, are of the utmost value. Theoretically speaking, we believe that there is no good object gained in aiming at a cement of over 110 lbs. to the bushel. Indeed we doubt if any cement deprived of its core by passing it through a 40 × 40 mesh sieve could be made to surpass this weight.

A great impediment to the sand test is

the fancied difficulty of obtaining a sand of uniform quality. A pure quartz, crushed to a powder which shall consist of grains rejected by a sieve, say, of 2,500 meshes to the square inch, but deprived of all grains too large to pass through a sieve containing 900 meshes, could be procured all over the country, and would surely be sufficiently uniform for the purpose. The section for fracture which had been selected in Germany of only 5 square centimeters, certainly appears small for the briquette; but we must remember that the smallest sectional area capable of giving reliable results is the one which will expose us to the smallest margin of error, due to imperfection in filling the mould, and gauging the compound of cement and sand. Whenever the sand test becomes adopted by English cement users, we expect to see the area of $1\frac{1}{2}$ inch by $1\frac{1}{2}$ inch selected, in preference to the standard area of 0.78 square inch chosen in Germany.

The last and perhaps the chief objection to the German sand test is the twenty-eight-day period, which must intervene between the testing and use of the cement. We are not yet quite certain that an interval of more than fourteen days is necessary, and by adopting this limit, with two instead of three parts of sand to one of cement, we think the chief argument against the sand test would disappear. It is a matter which no longer admits of any doubt, that for many of the dense cements now in such high favor with our English engineers, the seven-day test does not permit of a sufficient amount of induration to show the action of the cement at its best, as compared with a lighter cement tested in a similar way. The sand test, strangely enough brings out the high quality of a cement much more effectually than the mode of testing now in use, and admits of far more uniformity in the results.

It is a pity that no central body exists in this country, capable of uniting all the principal men interested in the employment of Portland cement, either as architects, engineers, builders, or manufacturers. Failing such a central authority, a joint meeting of the Royal Institute of British Architects and the Institution of Civil Engineers might be convened to report on this matter, as was done in Germany, and to decide upon some uniform plan of testing. We see no reason why this should not be accomplished, to the great benefit of all English users of Portland cement.

A FEAT IN TRIANGULATION.

From "Nature."

A NOTEWORTHY advance in geodesy has recently been accomplished by the junction of the network of measurements covering a large portion of the surface of Europe, with the African continent. The entire triangulation of Algeria was completed by French engineers some time since, and extended to the edge of the Sahara, in lat. 37°. M. Perrier, who had directed in a great measure the triangulation of Algeria, has for the past eleven years been seeking the means of joining the network in that country with the perfect trigonometric system covering the surface of Spain, France, and England. The importance of such a junction is easily appreciated when we consider what notable changes in the accurate conception of the shape of the earth and of the length of meridians has been effected by measurements on a much smaller scale.

For such an undertaking the most careful and painstaking preparations were requisite. As the result of his reconnaissances between 1868 and 1872, M. Perrier found that from all the trigonometric points of the first order between Oran and the frontiers of Morocco, the loftier crests of the Sierra Nevada on the Spanish coast opposite, were visible in exceptionally clear weather. Arrangements were subsequently made with the Spanish Geographical Institute for the mutual and contemporaneous execution of the proposed plan. A corps of Spanish officers, under the direction of the well-known General Ibanez, was detailed for this purpose, while the French Minister of War placed a division of officers from

the *Etat-Major* under the command of M. Perrier. The leaders chose for stations in Algeria the summits of Mount Filhaoursen and Mount M'Sabiha, west of Oran, and in Spain the summits of Mount Tetica and Mount Mulhacen, the latter of which is the most elevated point in the kingdom. The directions and distances between these four points were computed as carefully as possible, and preparations were then made for the final and determinative observations. At the Algerian stations the nature of the country and its inhabitants necessitated the use of a numerous force of soldiery as well as of means of transport.

In order to insure the accuracy of the observations, which required the passage of signals over a distance of 270 kilometers, it was decided to make use of solar reflectors and powerful lenses. The efficacy of such apparatus for even greater distances had already been tested by M. Perrier; still for the measurements in question they appear to have utterly failed to answer the expectations based upon them, not a single solar signal being visible from any station. Fortunately, the success of the observations did not rest entirely upon this one system of signals. Preparations had likewise been made for the employment of the electric light, and on the summit of each mountain one of Gramme's electro-magnetic-machines worked by engines of six-horse power had been placed into position.

On August 20 last, all the stations were occupied, and the electric lights were displayed throughout each night. Then the patience of the observers was submitted to a lengthy proof. The mists rising from the Mediterranean totally prevented the exchange of signals, until after a delay of twenty days, one after another the electric lights became visible even to the naked eye. Perrier compared the intensity of the light on Tetica nearly 270 kilometers distant, to that of α in Ursa Major, which rose near by. The observations were continued from September 9 to October 18, when this task for which such extensive preparations had been made, was completed in the most satisfactory manner. With its completion we come into possession of trigonometric measurements of the most exact nature, extending from lat. 61° in the Shetland Islands, to lat. 34° on the southern frontier of Algeria.

The extension of this network southward and eastward in Africa, desirable as it is for the elucidation of many nice points in geodesy, is unfortunately scarcely possible in the immediate future, and science must rest content with gaining a foothold in the great continent.

A Hugh Gasholder.—Messrs. Ashmore & While, of Stockton-on-Tees, have just secured a contract for the erection of what will be the largest gasholder in the world. It has been designed by Mr. George Livesey, for the South Metropolitan Gas Company. It is of the kind known as treble lift. The inner vessel is 208 feet diameter by 53 feet 6 inches deep in the sides; the middle vessel is 211 feet diameter by 53 feet 3 inches deep; and the outer vessel 214 feet diameter by 53 feet deep. It will thus be seen that when full, the top curb of this holder will be approximately 160 feet high above the tank water-line. The cubic capacity of the vessel will be 5,000,000 feet. The holder when at work will be retained in its position by means of twenty-four wrought iron stanchions, constructed of plates, bar, and angle iron, tapering from 28 feet wide at the base to 22 feet at the top, and 165 feet high, or thereabouts. These are connected laterally by a series of strong horizontal struts or girders of + section, and by diagonal braces of flat iron, increasing in strength from the top downwards. The tank containing this enormous vessel, and supporting the framing referred to, is in course of construction in concrete upon the special plan designed also by Mr. Livesey. What a contrast we have here between modern gas engineering and the time, within the memory of many men, when a London gas company kept a few thousand feet stored in balloons for their customers; while the Chartered Gas Company was once so hard up for a gasholder, that it purchased a second-hand brewers' vat and used it for the purpose.—*The Engineer.*

RAILROAD SHAKES.

By S. W. ROBINSON, Department of Physical and Mechanical Engineers, Ohio State University.

Written for VAN NOSTRAND'S MAGAZINE.

THIS term may perhaps justly be applied to a sort of railroad malady, which so afflicts some roads that passengers riding over them are sure to suffer in consequence, without respect of person; and the remedy is not to be found in bolus or pellet. Indeed to become seasick on a railway train is of somewhat frequent occurrence, so severe are the storms of *railway shakes*.

When an engineer stakes out a railroad, great care is exercised in the "alignment"; and the rails must be adjusted with nicety to it. Deviations would look bad, and quite small ones could be detected by the eye alone. It is therefore quite essential that this be carefully attended to, though another alignment of even greater influence upon the train, but whose error is less easily detected by the unaided eye, is almost entirely ignored; and at best left to the mercy of the section men.

A person standing upon a straight railway track could, by sighting, detect an error of $\frac{1}{4}$ inch to the 100 ft. in straightness. Deviations vertically could be about as easily detected if the eye were to take a favorable position for examination. But the fact that nobody is likely to take the trouble to thus inspect the track is, it seems, taken as license for admitting errors to the extent of an inch or more to the 100 ft. There is many a track which, if the horizontal and vertical alignments were interchanged, would become astonishing objects to behold. No railroad man would approve such a track, and yet the effect of it, in shaking up a train, would be far less than before the interchange. A few considerations will suffice to indicate this.

First—Suppose a car to follow a track full of such horizontal inequalities, the vertical errors being nil: The whole car would be jogged about to the same extent; the top as much as the bottom. But the cars would probably not follow the track exactly, some of the short turns being dodged over, and to this extent the jostling would be modified. This would be still further relieved in trains where the couplers form comparatively rigid connectors, as adopted now on many roads.

For the sake of the comparison, suppose next, that the track errors are as usual, viz: vertical. Now first, if both rails rise and fall exactly alike or together, the car would rise and fall to the same extent; these displacements being the same as the lateral movements in the previous case, if the car followed the rails exactly. But because gravity compels the car to follow the vertical crooks exactly, and as it would hardly follow the horizontal ones, the passengers would suffer most from the errors in vertical. But in the second place the two tracks will not exactly duplicate each other's crookedness, one rail perhaps being lowest where the other is highest. Such a condition of track will of course greatly aggravate the jostling action; the car being tilted first to one side and then to the other. To get a little idea of this, suppose one rail to be exactly straight, and the other in error vertically. Then, at the point of a depression, for instance, of one inch, the tilt or rock of the car, with the straight rail the axis of motion will be one inch at every point in the arc of a circle, or rather surface of a cylinder struck through the car, about the straight rail as center or axis, the radius being the gauge of track. If the latter distance be $4'\ 8\frac{1}{2}''$, the passengers will be beyond this circle, and hence their displacement will be greater in extent than the $1''$ error in the one rail. Now if the two rails are in error, the possible disturbance will be about doubled, the effect of which is anything but pleasant.

Section foremen, who largely control this matter, should therefore be selected with care as possessing the skill necessary for securing the desired adjustment of track.

In the preceding, the terms horizontal and vertical, as applied to alignment, are used in the same sense as when applied by engineers to curves, as horizontal or vertical curves. Horizontal alignment has reference to the line, as

projected upon a horizontal plane, etc.

Perhaps too little credit is given in the above to the civil engineer, for the relative portions of attention devoted to the two kinds of alignment. The leveling instrument is one whose precision falls not very far short of that of the transit, and hence the center line, as given to the construction masters, may be faultless in every respect. But as this line consists of points only, and 100 feet apart, or possibly in some cases, less, it follows that the intermediate points may, without any wit or allowance of the engineer, be subject to considerable deviations, especially as this is mostly left in great measure to no better instrument than the naked eye. Right here is where the failure in alignment above complained of begins. A new road may evidently be thus quite at fault. And the more the track is doctored in after years for setting, treated with fresh ballast etc., the more it may get into error. As this almost reconstruction of the track is usually placed in charge of men of no high degree of mechanical judgment, or ocular precision, it is no great wonder that some roads ride very badly. It is very likely that the greater portion of the men who have this trimming of the track in direct charge, have no appreciation of any importance as attaching to the vertical alignment, each rail line being simply kept straight as viewed from above. But as the latter adjustment should receive especial attention as compared with the other, as previously pointed out, it seems to follow that the undenominated rule in practical force for the adjustment of tracks is about thus: *the attention given to each element of adjustment of railway lines is inversely as its importance.*

So far the comfort of travelers has been the chief point of argument. But no great stretch of thought is required to enable one to perceive that errors of track line are sources of danger. No railway train could follow a ram's horn at 50 miles an hour, or even 30. The tendency is not only to derailment, but to breakages of rails, axles, etc. A computation will show that in a train moving at the rate of 50 miles an hour; as any train averaging 30 may, occasionally, when passing over a convex vertical curve whose radius is less than 168 feet, the engine or car will leave the track altogether, and actually fly to where the rail makes its return to line. A jolt and a concussion is of course the result. Conversely at a concave vertical curve, with the same radius of 168 feet, the train will receive such a sudden bounce as to cause the strains upon rails, axles, etc., to be just double what would exist for a perfect track. The effect upon culverts and short bridges slightly out of line, where the speed is not slackened, can be imagned, if not guessed at.

The above considerations apply to straight tracks. As regards curves it is easily seen that greater difficulty will be encountered in attempting to secure perfect adjustment of rails. One fact in connection with the elevation of the outer rail should be noticed here. Doubtless many an observing traveler has noticed a considerable side thrust of car at striking the initial points of a curve. Also the termination of the curve is noticeable. If, however, the speed of train and elevation of outer rail be adapted to each other, it would seem that this should not be. The point to be noticed here is that in practice the center line of curve is usually made tangent to the center line of the adjacent straight track. This should not be so, because evidently the car should be so carried around the curve as to cause the least disturbance to its mass. To this end it appears that the center of gravity of a car should be so carried around the curve as to describe a path which is tangent to the adjacent straight branches. This is not the case in practice, the curved part of path being inside of its true position. To secure this tangency which is necessary for the best conditions, it will be necessary to set the rails outward, at curves, to an extent determined with due regard to the difference of level of rails, and height of center of gravity of car above road bed. Also one rail should be elevated, and the other depressed, instead of simply elevating the outer rail.

It would seem that all these desirable qualities of a road could not be secured short of the aid of a sort of preparatory school for section bosses, in which they are to have their understandings sharpened as regards proper adjustment of rails to line, consequences of error, etc. The weight of responsibility placed upon

them should be more dependent upon their success at the school. Certain simple instruments should be introduced into rail-line adjustment, and instruction in their use given at the school. For instance, to facilitate vertical adjustments, a simple mirror placed edge to rail, and at an angle of 45°, would enable the adjuster to sight along a line of rail by simply looking downward. An attendant can then be sent along to different points and note them for high or low. Another device should also constantly be in hand, which, by a level, will give the relative heights of the rails at opposite points. It could consist of a cross-bar of gauge length, with a leg at each end, and a level swinging to different settings. In use, one leg is placed on each rail line, with level at the proper point for "straight" or "curve," etc. An instrument might also be devised, having a telescope or not, which could conveniently be so set as to lie in the line of a straight track, or swing in the plane of a curved track. Then, with a rod of a length equal the height of instrument above rail, one could detect inequalities in line of curve.

Finally, it might be stated, that as a matter of fact the riding quality of different roads varies greatly, some of which are already nearly faultless. This would indicate that if all the men who trim up tracks were equal to the best, the comfort of passengers would be greatly increased, accidents diminished and discrimination between roads mostly disposed of.

THE ELECTRIC LIGHT.

By F. E. NIPHER.

In the *Philosophical Magazine* for January, 1879, p. 30, Mr. W. H. Preece gives a discussion in which he shows the condition to be supplied in electric lighting, in order to obtain a maximum effect. In eq. 2, p. 31, he gives for the heat distributed to the incandescent material

$$H=\frac{E^2 l}{(\rho+r+l)^2}$$

where ρ represents the battery resistance, and r and l represent the resistances of the connecting wires and incandescent lamp, respectively.

For n lamps joined up in series, we must substitute nl for l, while if joined in multiple arc, we must put $\frac{l}{n}$ for l. In either case, the value of H is found to be a maximum, when the resistance of the lamp system is equal to that of the rest of the circuit.

Mr. Preece then proceeds on the assumption that this condition cannot be complied with, if n is large, reaching the conclusion that the amount of heat liberated in each lamp, varies inversely as the square of the number of lamps. This is true in either of the two cases discussed by him.

If, however, we have n lamps, arranged in n' parallel circuits, in each of which we have n'' lamps, the previous equation becomes

$$H'''=\frac{E^2 \frac{n''}{n'} l}{\left(\rho+r+\frac{n''}{n'} l\right)^2}$$

With this arrangement it is *always* possible to supply the condition which makes H''' a maximum, entirely irrespective of the value of n. If

$$\rho+r=\frac{n''}{n'} l$$

we shall have

$$H'''=\frac{E^2}{4(\rho+r)}$$

or the total heat in n lamps, is independent of the number of lamps.

The heat generated in each lamp will then vary inversely as the number of lamps.

St. Louis, Dec. 30th, 1879.

SCIENCE AND APPLIED SCIENCE.

From "The Engineer."

It will probably surprise both engineers and grammarians to be told that applied science is not science. Nevertheless that is the doctrine which, at the present day, appears to be commonly held and even openly asserted. Of the latter fact two instances have lately come under our own notice. The first is one with which most of our readers will be already acquainted. The Institution of Civil Engineers has been lately sued in the courts of Westminster, to obtain payment of local rates on the ordinary seale corresponding to the house which it occupies. It of course declined the payment on the ground that, as a scientific society, it were exempted by Act of Parliament from such rating; but it was contended on the other side that the Institution was not a scientific body under the meaning of that act; and the real basis of this contention—stripped of certain side issues, easily to be explained—was briefly that the object which the Institution sought to promote was not science at all, but simply the art of the engineer. The second instance grew out of the proposal made last spring by Dr. Siemens, that the societies having applied science for their object, should be gathered together into one central building. In discussing that proposal it was generally admitted that the means at the disposal of those societies, including the munificent sum offered by Dr. Siemens himself, fell short of the full amount required to purchase a site, and erect a building such as would be really worthy of the occasion. It was not unnaturally suggested that Government, in some form or other, might be asked to make up the deficiency; and that the great range of buildings at Burlington House, presented by the nation free of cost to the Royal and other scientific societies, formed an admirable precedent for the granting of the request. But it was immediately answered that this precedent did not apply; that there was an essential difference between the two groups of societies; and that what the Government had done for the one group, whose members were votaries of pure science, they would by no means be inclined to do for the other group, whose members cultivated an art, and even in many cases made their livelihood by its cultivation. The importance of the issue even in the first case is not inconsiderable. The annual amount demanded of the Institution of Civil Engineers was not small; and of course the decision will affect all kindred societies which have now, or may have hereafter, houses of their own. But the importance af the second case is very much greater. It involves—as we shall show presently—the whole decision of the question, whether there shall be a central house of applied science in London or not; and further, it involves the general estimation in which applied science is to be held, and the attitude to be taken towards it by Government and by the public. We therefore propose to devote a few moments to the consideration of the subject.

What is the difference between a science and an art? Surely not—as these objectors would have us believe—that an art is applied, or in other words, is practically useful, and that a science is not. Such an assertion is disproved at once, if it needs disproving, by a glance at the "Proceedings" of any of our scientific societies. For example, among the galaxy of pure sciences represented at Burlington House, the Chemical Society holds a distinguished place. Among the transactions of that society we may easily find side by side, say, a paper by Bessemer or Siemens on the chemistry of steel, and a paper by some little known chemist on some less known mineral, lately found in infinitesimal quantities in Siberia. We have no wish to depreciate the scientific value of the latter contribution; but is the scientific value of the former less, because it may also be of enormous importance to the whole iron industry, and so to the world at large? Or again, supposing that we read, in the Proceedings of the Royal Society, the announcement of a paper on "The strains in a metal or wooden curved bar, under a pressure normal to the surface, the bar being hinged at one end and having the other cut at a

certain angle and resting against a similar bar." Would anybody doubt or deny that this was a strictly scientific paper on a somewhat abstruse point of the theory of elasticity? Yet this is precisely the subject of a paper which the Institution of Civil Engineers has been lately considering, only that it was described more shortly and simply as "Dock Gates." It is true that, by handling the question under the concrete form of "Dock Gates" the author was compelled to introduce a number of further considerations which largely increased the complexity and difficulty of the problem; it is rather hard if they are to be held also to deprive it of its scientific character.

In point of fact the distinction between art and science is nothing of this kind. The true distinction needs only to be stated in order to command assent. It may be expressed shortly by saying that science thinks, art acts. Science works by laws, art by rules. Science can be learned almost entirely by books; art almost entirely without them. Art instructs in the doing of a particular work; science investigates the principles on which the doing of it rests, and applies these to show how it may be done in the best possible way. A subject may be pursued almost entirely by art, or almost entirely by science; but very little work of real value is achieved without a union of the two. Let this real distinction once be apprehended, and it will be seen how it clears up the question at issue. Doubtless there is an art of engineering, and one which it is essential the engineer should learn; but wherever he may learn it, certainly it is not within the walls of the Institution of Civil Engineers. He learns it in the workshop, or in the field, and in the only way in which it can be learnt—that is, by the exercise of his own hands and his own eyes. He goes to the meetings of the Institution of Civil Engineers, and of kindred societies, not to learn the art of his profession, but the science of it; the science which will enable him to extend and apply his art to the best advantage. It follows that all such societies are, primarily and strictly, scientific associations. Doubtless in the communications read before them there is much—though far less than formerly—which deals exclusively with practical facts, and seems at first sight to be apart from science altogether. But the reason of this is that the subject matter of engineering is exceedingly complex and obscure. Its problems, traced to the source, nearly all lead up to some of the most abstruse branches of molecular physics. Science is as yet only groping her way amongst these problems, and it is impossible she should grapple with them successfully until she has a much larger number of facts at her command than she has at present. This is a complete justification of papers of a so-called practical character, so long as they do adduce new facts, and are not merely descriptions of what has been described before. Nor are these peculiar to engineering. In every branch of science papers recording experiments are eagerly welcomed; yet what are experiments but facts? A paper before the Chemical Society, for instance, can scarcely ever be anything but a record of ascertained facts; for as regards the discovery of laws, chemistry is far behind engineering. If, then, we were asked to define in one phrase what should be, and is, the main object of the Institution of Civil Engineers, we should state it as being to make engineering less of an art and more of a science. To such an object is science to refuse her recognition?

What we contend then is that engineering is looked at in its wrong light when it is viewed as a trade, or at the best an art—a mere matter of rule and practice; and that to be looked at in its right light it must be viewed—like chemistry or electricity—as a great and difficult science, the application of which happens to be of invaluable practical importance. It is just because it is commonly looked at in the wrong light that men have scouted the idea of public money being granted for a House of Applied Science; and conversely, it is just because engineering would thereby be put at once and forever in its right light, that we wish a House of Applied Science erected out of funds partly supplied by the public. Such a house would be a standing record of the fact that England recognized engineering as a science, and as a science to which she was herself indebted.

EXPERIMENTS ON THE TRANSVERSE STRENGTH OF SOUTHERN AND WHITE PINE.

By F. E. KIDDER, B. C. E.

Contributed to VAN NOSTRAND'S MAGAZINE.

THESE experiments were made under the auspices of the Scientific Society of the Maine State College during the months of October and November, 1879; and were running day and night for about forty days.

The pieces experimented with were: 1st. Five pieces of Southern or yellow pine (*pinus pâlustries*, L, or *pinus australis**), obtained from a lumber dealer of Bangor, Me., and stated to have been drying for four years, and also to have been kiln dried soon after being cut. These pieces were all taken from the same piece of plank, and were straight grained, and of an excellent quality. Their dimensions are given in Table A.

2d. Four pieces of white pine (*pinus strobus*) obtained from the same place as the Southern pine, and said to be of the same state of dryness. This lumber was cut on the west branch of the Penopscot river. All these pieces were also taken from one plank. These pieces would have been perfect but for some sap wood along one side.

3d. Four pieces of white pine taken from a plank which had lain three years in the attic of a hall, and which seemed to be very dry. These last pieces were almost perfect.

All of the pieces experimented with were of a very fine quality and were much better than can generally be obtained in large pieces.

As the pieces differed slightly from each other, it is thought best to give the quality of each, considering them all to be dry.

The principal object of these experiments was to obtain values of the modulii of rupture and of elasticity of these woods, of which the writer has never seen any satisfactory values published, and also to note anything that seemed to have any effect on the strength of the wood.

The method of making the experiments was as follows: The pieces were supported on two cast-iron frames, very carefully leveled, and placed exactly 40 inches apart. A scale pan was arranged so that it could be suspended from the middle of the beam by a $\frac{3}{4}$-inch bolt resting on the top, and could be raised from or lowered on to the beam by means of screws, as slowly and as gradually as could be desired. The deflections were obtained by fastening a vertical scale to the side of the piece at the center, and stretching a very fine silk thread across between the supports. By this method the deflections could be read to the hundredth of an inch. Although this method of obtaining the deflections was not as accurate as could be desired, yet the results show, I think, that it could have given rise to but very little error. In arranging for these experiments, and while making them, the writer was greatly assisted by Prof. Pike of the State College, for which he would here make acknowledgment.

To obtain the modulus of elasticity, each piece was subjected, at intervals of one or more hours, to loads of 27, 37 and 47 pounds, and the deflections noted.

The modulus was obtained from the deflections by means of the formula:

$$E = \frac{W l^3}{4 \Delta B D^3},$$

in which E = modulus of elasticity, l = the distance between supports in inches, Δ = the deflection, B the breadth, and D the depth, also in inches. The value of Δ used was the mean of the three values for each piece, and W was taken at 37 lbs. The sizes, deflections and modulii of the different pieces are shown in the following table:

* Determined by Mr. Ed. T. Bouve, of Boston, Mass.

Piece.	Kind of Pine.	Quality.	Def.	B	D	Deflections.			Mean Def.	Value of E.
						27 lbs.	37 lbs.	47 lbs.		
			in.	in.	in.	in.	in.	in.	in.	lbs.
No. 1	Yellow	Perfect	40	1.24	1.24	0.11	0.14	0.19	0. 14⅜	1,707,282
No. 2	"	Fair	40	1.23	1.24	0.10	0.14	0.185	0.142	1,777,719
No. 3	"	Good	40	1.23	1.23	0.10	0.14	0.19	0. 14½	1,804,487
No. 4	"	Perfect	40	1.23	1.23	0.10	0.14	0 17	0. 13⅝	1,892,510
No. 5	"	Excellent	40	1.24	1.24	0.10	0.13	0.16	0. 13	1,926,161
No. 6	White	Excellent	40	1.5	1.5	0.06	0.08	0.11	0. 08½	1,403,259
No. 7	"	Good	40	1.49	1.49	0.07	0.10	0.12	0.096	1,251,252
No. 8	"	Excellent	40	1.49	1.49	0.07	0.08	0.115	0.088	1,365,002
No. 9	"	Excellent	40	1.5	1.5	0.06	0.085	0.11	0.085	1,375,746
No. 10	"	Excellent	40	1.5	1.5	0.06	0 08	0.11	0. 08½	1,403,259
No. 11	"	Perfect	40	1.5	1.5	0.06	0.08	0.10	0. 08	1,461,728
No. 12	"	Excellent	40	1.5	1.5	0.06	0.08	0.11	0. 08⅝	1,386,000
No. 13	"	Excellent	40	1.5	1.5	0.06	0.08	0.10	0. 08	1,461,728

Average value of E for yellow pine, 1,821,630.
" " " " " white pine, 1,388,497.

From this table we see, 1st., that the deflections are proportional to the weights, the dimensions being the same; 2nd. That for the pieces of yellow pine, the values of E varied from 1,707,282 lbs. to 1,926,161 lbs., and average 1,821,630 lbs; and 3rd. That the values of E for the pieces of white pine, vary from 1,251,252 lbs. to 1,461,728 lbs., and average 1,388,497 lbs.

In breaking the pieces, a washer of about 1¼ inches outside diameter, was placed over the bolt that rested on the piece, to prevent its cutting into the wood. The pieces were not all broken in the same manner. Some had heavy loads resting on them for several hours, while others were broken in a comparatively short time. Very complete notes were taken of the deflections under the different loads, the length of time they were applied, the length of time between any two successive loads, the manner in which the pieces broke, etc.; but it would occupy to much space too present them here.

The following table gives the deflections of the pieces, under a few of the loads, the length of time the loads were allowed to rest on the beam, the breaking weight, ultimate deflection, when it could be observed, and the modulus of rupture R.

In all the above cases, the deflections

Piece.	Weight.	Time.	Def.	Weight.	Time.	Def.	Breaking Weight	Ultimate Def.	Modulus of Rupture R.
	lbs.	h. m.	in.	lbs.	h. m.	in.	lbs.	in.	lbs.
No. 1	125	17 00	.54	150	17 00	.68			
"	200	40 00	.91	250	17 00	—	390¾	1.84	12,291
No. 2	Thrown out, on ac count of gnarl in wood.								
No. 3	275	16 00	1.20	300	0 05	1.36			
"	320	0 05	1.44	337	0 05	1.66	402	——	12,967
No. 4	350	1 30	1.20	380	22 00	1.74			
"	390	18 30	1.90	423½	0 05	2.00	454½	2.18	14,654
No. 5	390¼	0 00	1.72	Broke in 1h. 30 min.			390¼	——	12,280
No. 6	200	17 00	.46	300	1 00	.73			
"	385	1 30	1.67	430½	1 15	1.43	454½	——	8,080
No. 7	390¼	0 40	1.20	404½	2 15	1.40	439½	1.60	7,973
No. 8	423	12 00	1.48	478	0 00	1.68	495½	2.12	8,982
No. 9	390¼	0 00	.88	430	0 00	1.12	492¼	1.72	8,751
No. 10	392¼	40 00	1.30	403¼	4 00	1.40			
"	412¾	2 00	1.42	421½	16 30	1.79	440	1.91	7,822
No. 11	390¼	0 00	.86	502	0 00	1.32	531	1.92	9,440
No. 12	415½	16 00	1.64	428¼	0 00	1.70	436	1.90	7,751
No. 13	404¼	1 05	1.12	415¼	0 00	1 20	426¼	1.24	7,578

Average value of R for yellow pine, 13,048 lbs.
" " " white " 8,297 "

are those taken at the end of the time the weight was allowed to rest on the beam, being sometimes much greater than when the weight was first applied. The value of R was computed by the formula $R=\frac{6Wl}{4BD^2}$, in which W the breaking weight, and the other letters have the same values as in the formula for E. Although these experiments were not sufficiently complete to determine any law regarding the diminution of the breaking weight, by subjecting the piece to frequent strains, not sufficient to break it, yet it seems to me that they show very plainly that the breaking weight is considerably lowered, by subjecting the piece to such strains.

As a result of these experiments, I find for the average values of:

The modulus of elasticity of the yellow pine...	1,821,630 lbs.
The modulus of elasticity of the white pine....	1,388,497 "
The modulus of rupture of the yellow pine...	13,048 "
The modulus of rupture of the white pine....	8,297 "

These values are larger than those given by earlier experimenters on American woods; but the values for the yellow pine, are somewhat less than those obtained by Prof. R. H. Thurston, as published in the *Journal of the Franklin Institute*, for October, '79. The values given there are:

	E.	R.
White pine	883,636 lbs.	5,280 lbs.
Yellow "	3,534,727 "	16,740 "

The value of E for yellow pine is certainly larger than that given by other authorities for *any* wood. The white pine, he states, to have been of a poor quality, which probably accounts for the low values of E and R.

In an article, published in Vol. XIX, page 8, of this Magazine, Dr. Magnus C. Ihlseng gives as the values of the modulus of elasticity of two pieces of white pine, determined by means of vibrations, 1,278,100 lbs. and 1,577,890 lbs. Taking the mean of these two values, 1,427,990, it does not differ very greatly from the average value derived from these experiments. Although these experiments are not complete enough to determine the true values of E and R, for perfect pieces of wood, yet it seems to me, that the values obtained are perfectly safe for use in calculation, and are more correct than most of the values now published.

ABSOLUTE ZERO OF TEMPERATURE.

By DE VOLSON WOOD, A. M., C. E.

In the November number of this Magazine, on p. 368, we find the following, taken from the *Revue Industrielle*:—"In the present state of our knowledge of the subject, nothing justifies the assumption of an absolute zero, and it is one of those false assumptions that tend to retard the development of science." An examination of the reasoning of that writer shows that he is not warranted in making his conclusion. He sets up a man of straw and proceeds to demolish him. He says, "consider for instance a gas whose volume is unity at a certain temperature. If the temperature be raised one degree, the volume will become $1+\alpha$; if raised one degree higher, its volume becomes $1+\alpha+\alpha(1+\alpha)=(1+\alpha)^2$, &c." Here is the fallacy. Experiment shows that the volume, in the second case, will be $1+2\alpha$; and generally $1+\alpha\,t$, instead of $(1+\alpha)^t$ as given by that writer. No explanation is given—it is a bare assumption.

The absolute zero of temperature, if it be a reality, is not within the limits of experiment. But if it has no real existence, it is not necessary to abandon its use, so long as the quantities reckoned from that point *are true within the limits employed in practice*. That they are practically true within these limits, has been abundantly verified by experiment. That the law would change if the temperature could be reduced to near the assumed absolute zero is not improbable; but since the lowest temperature ever observed is more then 200° above that point, and as this is many degrees lower than is actually reached, it is not ne-

cessary for the engineer to inquire what might take place if the temperature could be reduced to 10°, 50°, or even 150° above zero—although it may be a matter of speculative interest to the physicist. Practically, the absolute zero is a reality.

ERRATA.—In the article on "Arch Bridges," in the January issue of this magazine, certain typographical errors require correction, as follows:

On page 35, first line should read S=, &c.

In the eleventh line, "*dx*" should end the 10th line.

In the sixteenth line, "*slightly*" should be *directly*.

On page 37, Eq. 9 should be

$$y'+y''=y \quad (9).$$

On page 37, in Eq. 10, the denominators of the exponents should be n instead of x.

Also in the seventh line from the top of the second column of page 37, $5x110$ should 5×110.

On page 38, in the parenthesis of the eighteenth line of second column, the word *one* should be *our*.

The same correction is required in the twentieth line from the bottom of the first column of page 39.

REPORTS OF ENGINEERING SOCIETIES.

ENGINEERS CLUB OF PHILADELPHIA.—At a meeting of the Club held December 20th, Mr. Fred Lewis read a most valuable paper "On the Angular Pitch of Square-threaded Screws." When the screw is used as a means of conveying power, the square thread is the common and approved form, but no special standard of pitch is strictly adhered to, and inclinations ranging from 5° to 30° are often used. The efficiency of a screw is increased by the reduction of its frictional work, which will be found to depend upon the coefficient of friction, the angular pitch of the thread, the shape of the thread and the diameter of the supporting step or collar.

It is therefore desirable, in cases where the screw is used to convey power, that its frictional resistances be reduced to a minimum; and it was the object of this paper to investigate the relation between angular pitch and frictional work, and to derive a general formula by which the angle corresponding to the least amount of frictional work can be determined.

After elaborating the formulæ, Mr. Lewis has constructed two diagrams, from which one can readily find the most advantageous pitch with least sacrifice of power or material for a screw. In diagram 2 it is shown that by a change from an ordinary collar to stepbearing, that a screw whose pitch was 5° might be increased to 13° without sacrifice of power and with a saving of .6 of the work consumed by friction.

Mr. Lewis cited many instances in which the application of the formula for determining the pitch of screws would lead to a great saving of power, and also gave a full description of apparatus used and manner of conducting his experiments.

A communication from M. Pontzen, of Paris, requesting information upon the the subject of narrow gauge railroads and street railways was read. The Secretary will be very glad to receive any information or data upon these subjects either from members of the Club or others, and due credit will be given for such.

Prof. Lewis M. Haupt exhibited a new form of transit rod, which consists of a hollow brass rod about ⅝ inch in diameter, loaded at one end, and held by the rod man with a thimble joint. Its perpendicularity is thus insured, and its small size makes it a much more accurate instrument than the old style wooden rod. The rod has been used extensively and found perfectly satisfactory. Its weight is about the same as an ordinary ash rod.

Mr. Hering introduced Messrs. Vaux & Clime, who exhibited and explained to the Club a new form of turbine, which it is claimed gives much better results in practice than the old forms.

Mr. Hering also exhibited a trap-valve for preventing the escape of foul air into houses from closets, sinks, etc., which has been invented by Mr. Gorman. This valve is made upon the same principle as a sewer trap described to the Club last spring by Mr. Gorman. It is a balanced valve, consisting of a plate, hung on brass axis fastened in back part of pipe. The counter-weight in the valve is adjusted by a filling of lead, according to the number of wash-stands, closets, etc., about the valve. By allowing the valve to strike against a lead-bearing a tight joint is always obtained.

Mr. Ashburner read some notes upon a recent test of aneroid barometers which he had made in the East Norwegian Shaft, near Pottsville, Pa. The shaft is 1585 feet deep. In descending the shaft, the Hicks barometer which he carried marked 1590, and in ascending, 1575. Mr. A. said that this is the most accurately working barometer he ever carried, and in the experiments he had noted a number of points which he thought might be of practical value. The instructions given in most text books are that it is necessary, after making a rapid ascent or descent, to allow a few minutes for the barometer to come to its bearing, but it was noticed in these experiments that the instrument came to its bearing inside of ¼ minute, and did not change in the next ten minutes. Instances of remarkably good results in obtaining elevations by barometric work were cited by Messrs. Ashburner, Young and Billin, and general discussion ensued.

Mr. Billin read extracts from a translation by himself of a very interesting paper on Dephosphorization of Iron, read by Mon. Gautier before the Society of Civil Engineers of Paris.

IRON AND STEEL NOTES.

In former times it has been observed, when iron was made in small forges and at comparatively low temperatures, in a similar manner to that still employed in certain half-civilized countries, the greater part of the phosphoric acid passed into the ferriferous slag, and good malleable iron was finally produced tolerably free from phosphorus. The following is an analysis of a scoria produced in Roman or Etruscan times from the specular ore of Elba, which usually contains about 0.04 per cent. of phosphoric acid:

Iron protoxide	76.49	per cent.
Alumina	2.57	"
Manganese protoxide	0.60	"
Lime	1.32	"
Magnesia	0.64	"
Zinc oxide	0.20	"
Sulphur	0.40	"
Phosphoric acid	0.34	"
Silica	14.20	"
Oxygen and not estimated	3.88	"
	100.00	"

This specimen was taken from a large heap of many thousands of tons of scoria lying on the beach close under the site of Populonia the Etruscan Pupluna, a town much famed in those times for its iron and copper manufactures. It furnished Scipio with iron in the second Punic war. It is now a deserted site, and but few traces of its former importance remain.

It is of interest to observe in the above analysis that the phosphoric acid is about eight times as much as in the natural ore.

I obtained in February, 1878, a piece of metallic iron from the same district; it originally weighed about 2 kilos., and was somewhat rusted. It was found among scoria in the vicinity of Campiglia, and gave on analysis:—

Combined carbon	0.873	per cent.
Graphite	2.853	"
Silicon	0.544	"
Sulphur	0.096	"
Phosphorus	0 090	"
Manganese	0.091	"
Iron sesquioxide	2.430	"
Metallic iron	92 804	"
Moisture	0.092	"
		"
	99.873	"

Of the antiquity of this specimen there is some doubt, but it has certainly not been produced in recent times. The high percentage of carbon cannot be adduced as indicative of its modern origin; the researches of Lowthian Bell proving that carbide of iron in contact with iron oxide in the molten state is not necessarily decarburised. Similarily, therefore, the above specimen might have been made contemporaneously with a richly ferruginous scoria, such as the Roman or Etruscan metallurgists produced. The ancients possibly new iron both cast and wrought, as well as the intermediate steel. Pliny says that iron was made in a similar manner to copper. Making a comparison between puddling and copper smelting, he notes the "remarkable fact that when the ore is fused the metal becomes liquefied like water, and afterwards acquires a spongy brittle texture" (xxxiv., 41), which goes to imply that iron first "came to nature" considerably previous to the days of Mr. Cort.

Cast-iron recently produced from Elba ore near the same locality contained three times the quantity of silicon present in the above analysis, the constituents being as follows:

	I. Per cent.	II. Per cent.	Mean Per Cent.
Carbon	4.306	4.147(diff.)	4.306
Silicon	1.672	1.676	1.674
Sulphur	0.067	0.056	0.067
Phosphorus	0.110	0.108	0.109
Manganese	0.748	0.757	0.753
Iron	93.256	93.256	93.256
	100.159	100.000	100.165

LARGE FORGINGS AND THEIR MATERIALS The object of this paper by Mr. G. Ratliffe, is to show that a forging made from built-up and welded steel blooms, being of a fibrous and well-worked character, is better than a forging from a single cast ingot. It is, he says, most important to convert the crystalline into as fibrous a nature as possible, and this is better done by rolling than by any other known process. He now takes the ingots, made of a specially mild quality of steel, and rolls them down to bars, so that a fibrous material is the result, and the crystalline structure of the ingot is got rid of. These bars are sheared into suitable lengths, and piled together in order to make the required forging. Keels, stern-frames, and other forgings, of awkward shapes, can now be made of steel, and vessels built entirely of this material, where hitherto they have been only partially so constructed, with great disadvantage in several respects. The author gives the results of a large number of tests of the material described. which are of a very highly favorable character. He urges the necessity of using a very ductile steel for forgings, objects to the use of single cast ingots because of the great difficulty in working them, and in illustration of the apparently unsatisfactory character of hard steel for some forgings, referred to the recent report of the Board of Trade on railway casualties, which shows, among other things, that "of the thirty-six crank or driving axles, twenty-four were made of iron and twelve of steel The average mileage of twenty-one iron axles was 193,999 miles, and of ten steel axles 168,472 miles." As there may be a very great many more iron axles running at the present than there are of steel, the above figures do not speak very much in favor of steel for this use; but the failures would probably have been very considerably less if the steel had been worked and welded as described.

Respecting iron forgings, Mr. Ratliffe says, that as most of the scrap from which these are made is shipyard scrap it is of a very common quality, and cannot make good ductile iron. The best selected scrap is, he says, uncertain; and owing to the varying qualities of iron we

are so liable to get, we cannot insure a material of uniform quality, but often find seams or black marks, which are by so many engineers considered sufficient to condemn almost any finished shafting.

The author stated that the cost of making forgings of mild welded steel is considerably less than that of making them from large ingots, and that it gives the further advantage of certainty that the material is properly worked, which, he contends, is not the case with an ingot. The author described some experiments made by exploding charges of gunpowder in cylinders of the welded steel, with the object of showing its suitability for guns and armor-plates, experiments that might suggest its suitability for the former, but useless as indications respecting the latter.

RAILWAY NOTES.

STEAM TRAMWAYS IN ITALY.—The line Bergamo-Treviglio Lodi has been open to the public from Bergamo to Treviglio since the 1st September, and the other half from Treviglio to Lodi is now in course of construction. The provincial road on which the rails are laid, is more solid than any other known, and so hard that in many places blasting was employed for laying the sleepers. The gauge is the same as adopted for all Italian railways, viz. 1.445 metres. The rails, supplied by one of the first works in Rhenish Prussia, are of Bessemer steel, and weigh 18.600 kilogs. per running meter. The accessories for fixing the rails were made in Italy. The sleepers are of the following dimensions—2.30 by 0.17 by 0.12 meters, and altogether of the best and soundest oak of Lombardy. The carriages are of first, second, and third class, both closed and open on the sides—called *jardinieres*—and closed, and open trucks for the transport of goods and cattle; all of these are built by a firm in Milan, which has supplied the rolling-stock to almost all similar lines in Italy, and is now building the carriages for account of the Tramways and General Works Company in London, who are constructing a line in continuation of the Tramways Pistorius. Tramway extension is already occupying a great deal of attention in some of the chief Italian cities, and the value of light railways, as means of intercommunication between villages and towns in directions not served or likely to be served by railways, is generally acknowledged. The engines are of the well known factory of Messrs. Henschel and Son, in Cassel, Germany, The trains are usually composed of four carriages, capable of carrying on an average 150 passengers each journey. The rails are laid in a single line on one side of the high road, and in the villages there is a double line for the depth of about 80 meters. The goods service is done during the night. At the extremities of the line, in Bergamo and Lodi, and in the central point at Treviglio, there is a passenger station composed of a waiting-room, buffet and office for the station master; also sheds for engines and carriages, which occupy an area of about 3,000 square meters. Besides there is at Treviglio a well-furnished repairing shop and magazine for sundry material. The line has a total length of about 45 kilometers, and passes through fifteen towns and villages. The above may give an idea of the nature and importance of the line. Whoever knows Italy and the high cost of ordinary railroads, must be convinced of the utility of the largest extension of such steam tramways.

THE *Inter-Ocean* has been collecting statistics of railway tunnels, and finds the more important of such structures to number 957, with a total length of 291 miles. They are distributed as follows: Great Britain, 140 tunnels and 87½ miles; France, 259 tunnels and 82.6 miles; Belgium, 20 tunnels and 4 07 miles; Germany and Austria, 270 tunnels and 51¼ miles; Italy, 76 tunnels and 19¾ miles; Switzerlaud, 5 tunnels and 4.08 miles; North America, 115 tunnels and 33 miles; South America, 72 tunnels, and 9 miles. Of English tunnels the most noted for magnitude and difficulty of construction is the Kilsby on the North-Western Railway, length 1.33 miles, cost $1,500,000, chiefly from nearly a fifth of its length being in quicksand saturated with water. The Nerthe tunnel in France is nearly three miles long, and cost $2,090,076; the Blaizy tunnel 2½ miles. The largest tunnels in Germany are between Offenburg and Constance. There are 15½ miles, 29 tunnels of various lengths, the longest 5,600 feet. The longest and most interesting tunnel in Switzerland is the Hanenstein, 1½ miles long. The one of chief interest in Italy is the Mont Cenis, 7½ miles in length. The principal tunnel in America is the Hoosac tunnel, which is 4.75 miles in length. The Mont Cenis tunnel is the longest railway tunnel.

A CURIOUS contrast of the proportionate receipts and expenses on railways is afforded by some official statistics in regard to the Great Northern Railway—one of our typical passenger railways. These facts may correct some misapprehensions as to the sources of receipts and expenditures on railways, and the contrast afforded by little more than three years' working is instructive. Four years ago the receipts from passengers, parcels, mails, &c., were equal to 4.89s. per train mile; in the last half of last year—corresponding half-year—they were 4.28s. per train mile; and in the first half of this year they had sunk to 3.73s., it being always borne in mind that the latter half of the year is the more remunerative one. In 1875 the receipts from merchandise and mineral traffic were reported as equal to 5.48s. per train mile; in the corresponding half of last year the receipts from these sources were 5 52s. per train mile; and in the first half of the current year they were 5.39s. per train mile. Adding other slight items of expenditure, the receipts over the whole train mileage—passenger and goods—of the company were, in the earlier year, at the rate of 5.29s. per train mile; in the corresponding period of last year, 4.99s.; and in the first half of the present year, 4.69s. Thus though the gross receipts of the company are increasing, they are not increasing so rapidly as is the train mileage, the running of which

earns them. As to the expenditure, the figures are instructive also. Four years ago the maintenance of way, works, and stations cost 6.20d. per train mile; in the corresponding half of last year it cost 5.91d.; and in the first half of the present year the cost was 5.63d. For locomotive power the charge was, in the earliest half-year named, 8.69d.; in the contrasting half of last year, 7.63d.; and in this year, 7.81d.—the change being chiefly due to the reduced price of coal. The traffic expenses are the costliest item; they were, four years ago, 11.18d. per mile; at the end of last year, 11.0d. per mile; and at the present time, 10.60d. per mile. Compensation has fallen from .78d per mile to .67d. and .55d.; law charges are practically unchanged, and general charges have fallen .20d. per mile. The only noticeable increases are in the cost of repairs to carriages and wagons, and in rates and taxes. The total cost was, four years ago, 2.77s. per train mile; and, in the corresponding period of last year, 2.66s., whilst for the present year the amount has been 2.63s. The reductions, therefore, in the expenditure have not been so large as those in the receipts. In the cost of many materials there have been large reductions, but there has not been an application of the pruning knife so fully in other directions, and it is probable that on our chief railways the example set by the North British in the reduction of salaries and wages may have to be followed.

ORDNANCE AND NAVAL.

Woolwich and Krupp Guns. On Thursday afternoon, August 11th, one of our 80-ton guns intended for the Inflexible was fired in the Royal Arsenal, with results which have been justly noticed in the daily papers as very important, though slightly exaggerated. It appeared satisfactory indeed that so soon after we had been astonished at the results obtained by Krupp's 71-ton breech loader, our own gun should even surpass its achievements, and this was stated to be the case now. However much we should naturally share in the satisfaction thus expressed at so good a result, it is necessary to examine the facts carefully in order to guard against the mistake of taking credit for something more than has been really achieved. Such caution is clearly called for when the first reports on which the commendations are based leave out what is absolutely essential to enable us to determine whether there is cause for congratulation at all. We refer, of course, to the *pressure* developed in the bore, which was not mentioned in any of the first reports. A very little thought will show the necessity for knowing this condition. We may surely all suppose that a considerable margin of strength must exist beyond that which will enable any gun to bear the strain of an ordinary service round. Suppose, then, that the Krupp gun obtains a result with what its maker considers its proper service charge, which result is better than that given by our own 80-ton gun fired with its own surface charge—it stands to reason that we may be able to fire a round with a larger charge than that for ordinary service, and so obtain a better result on any given occasion, without perhaps over-straining our gun. Such a round would be an exceptional one, whose results must be treated as exceptional, and which would mislead the public if not so described. Whether any actual experiment ought to be entered in such a catagory, or to be treated as good for general purposes, entirely depends on what pressure was exerted on the bore of the gun; if such pressure was low enough for the gun to stand habitually, it does not matter whether the round in question was supposed to be exceptional or not; for it is manifest that such conditions might for the future be allowed on service. It is clearly necessary, however, that we should know the pressure developed in the bores in order to compare the results obtained with any two guns. Now it happens that the round fired with the 80-ton gun was actually a proof round, not one intended to be employed ordinarily on service. It may be replied that we have no guarantee that Krupp's was not the same. Let us then come to the question of pressure, which, with the other conditions, will enable each result to speak for itself. In giving these results we have to make a correction in the weight of the projectile of the 80-ton gun as given in the daily papers, namely, a deduction of 60 lbs., and on that of Krupp's quoted with it, of no less than 74 lbs. At the same time we have to explain that, in going over the printed reports of the Meppen firing, with the results recorded on the ground, we find that we have in one case, by some accident, a wrong velocity printed, namely, 1602 feet instead of 1648 feet. It is well, then, to give here the actual conditions of each round concerned, as we believe to be correct, within small limits. The 71 ton Krupp gun at Meppen on August 5th, fired a projectile weighing 1,712 lbs. with an initial velocity of 1,648 feet per second; the pressure on the bore was 19.85 tons, the projectile having, consequently, 32,242 foot-tons of stored-up work. This, with the calibre of 15.75 inches, gives a penetrating figure of 651.61 foot-tons per inch circumference, and, with the ordinary formula and factors employed in the service, a penetration of 32.12 inches.

The 80-ton gun at Woolwich, on September 11th last, fired a projectile weighing 1,700 lbs. with an initial velocity of 1,657 feet per second, and a pressure of 21.5 tons, having 32,366 foot-tons stored-up work, which, with a diameter of 15.92 inches (taking the windage off the 16 inches), gives a penetrating figure of 647.15 foot-tons, and a penetration of 31.98 inches. Comparing these two, we see that the Woolwich gun has rather more stored-up work, and would strike rather the more severe blow of the two. This tells where actual penetration has not to be obtained, for example, against steel plates of suitable thickness. On the other hand, the Krupp gun would have rather more penetration. We may, however, call the two rounds equal to all intents and purposes, but can we say the same for the guns? The Woolwich gun has a pressure of 21.5 tons and the Krupp only 19.85 tons. If the former pressure is not considered too high, the question arises

whether we ought not in fairness to take the most powerful round that the Krupp gun has fired, when such a pressure has not been exceeded, Now in our report we gave the highest recorded result with the 71-ton Krupp, which may fairly be compared with a Woolwich proof charge. This was a projectile weighing about 1,715 lbs. discharged with a velocity of 1,703 feet per second, having, therefore, 34,490 foot-tons stored-up work, a penetrating figure of 697.05 foot-tons, and a penetration of 33.50 inch, with a pressure of 20.92 tons. Now this result decidedly beats that obtained at Woolwich, the penetration is 1½ inch more and the stored-up work 2,124 foot-tons in excess, while this is obtained with considerably less pressure on the bore. We think, then, that few will contend that this result is not superior to that obtained by the 80-ton gun. At the same time there is something yet to be said on the subject in favor of the Woolwich gun, and this makes it necessary to compare the guns a little more carefully. While the 71 ton gun is the lighter of the two by nine tons, it is very much the longer, the actual bore of this gun being 343 inches long, and that of the 80-ton gun 288 inches only; that is, there is 4 feet 7 inches difference in length of bore. It is this that enables the Krupp gun to develop so much work at so low a pressure, because the powder gas has a longer time to act on the shot; but we must give the 80-ton gun its due. If the gun is shorter and heavier, it is of course much thicker, and ought, therefore, to be stronger. The advocates of steel may question this, but for the moment we must refuse to consider the respective merits of steel and wrought iron. We can only compare two guns by comparing their features one by one, and any question yet unsettled such as this must not be allowed to stand in the way, as any arbitrary value might be claimed by the advocates of each kind of metal which would make any definite discussion impossible. For the moment, then, putting the difference in the nature of the metal on one side, we have the Woolwich gun 4 feet 7 inches shorter and 9 tons heavier than Krupp's, and therefore thicker and capable, if made of equally good metal of resisting a greater strain than Krupp's gun. Probably no two people would agree as to exactly how much greater strain it might bear, but certainly a comparison with equal pressures may be fairly objected to. The question then is a complicated one; we have shown that no comparison can be made without considering the element of pressure, but we end by finding that it is impossible to know exactly how much to allow when we have compared the pressures carefully. Probably most artillerists, our own included, will consider that the Krupp gun has decidedly the best of the comparison, without being able to say the precise measure of the advantage. Why is this? The 80-ton guns have actually been completed more recently than Krupp's gun; might we not have looked for a better result? The answer to this involves what is at this moment perhaps the most important question connected with heavy guns, namely, that of breech and muzzle loading. We will explain why. The 80-ton guns, although only recently completed, had their proportions determined four years ago. Subsequent experience has taught us the great advantage of increased length and slower burning powder, but we were unable to avail ourselves of our knowledge in this particular instance, for the guns are made to suit a turret vessel which has in the meantime been built, and the length of the gun is involved in some of the leading dimensions of the ship, because it has to be loaded from the muzzle. Had the pieces been breech-loaders it might have been possible to have altered their dimensions and increased their length, because it is hardly ever necessary to approach the muzzle of a breech-loading gun. In action we have literally nothing to do with it. Whether or no a breech-loading gun, projecting further out of its turret than was originally intended, clearly matters little in comparison with the question of any alteration in the length of a gun that dips its muzzle and is loaded from a certain fixed place constructed in a deck every part of which has been carefully worked out, and which involves the design and structure of the ship itself. Once more, then, we are brought to see the advantages recently obtained by breech-loading guns over muzzle-loaders. We pointed out in our article of September 5th what an advantage the breech-loader had as the length became greatly increased, or again if the chamber were greatly enlarged; to these may be added that the length can be altered if desirable without necessitating any serious alteration in a vessel necessarily designed long before she is equipped; and, lastly, that it now seems to be acknowledged that the breech-loader has beaten its rival in accuracy of fire.

Once more, to return to the recent trial of the 80-ton gun, we may say that, regarded as an effort to obtain a good result from a gun whose length is certainly not what would be assigned to it in the light of recent investigations, the success has been great. By carefully chambering and adjusting the charge, much has been done to utilize thickness where we should have preferred length; but if we were to go further, and were to suppose that our 80-ton guns are better proportioned and superior to the guns recently designed at Essen or Elswick, we should make a great mistake.

ENGINEERING STRUCTURES.

INUNDATIONS AND EMBANKMENTS.—At a recent meeting of the French Academy, Gen. Morin made an interesting report on the works of Engineer Dausse relative to embankment of the Tiber at Rome. Extending the question, he studied the inundations of large rivers in general, with the best means proposed for preventing their terrible effects. The recent catastrophe which destroyed a populous city in Hungary renders the subject of much public interest at present.

At Rome, the flood of the Tiber in December, 1870, caused grave disasters The ever-increasing obstruction of the river exposes to

inundation several closely-populated quarters, and the principal public monuments.

An inquiry was set on foot by the Italian Government. The Commissioners thought they must exercise great reserve with reference to the solution of the problem proposed by M. Dausse, viz., deepening of the present bed of the river so as to restore the navigation, at present interrupted. The project of the Government was to keep the river, in its passage through Rome, between quay-walls 18 meters in height, and higher than the level of the neighboring streets.

Taking up, first, the question of the embankment of rivers, Gen. Morin indicates the inconveniences and dangers of certain arrangements that are thought to be preservative.

A study of the *régime* of great rivers is necessary in order to appreciate the real value and utility of embankments.

In rivers with movable bottoms there are often formed deposits which hinder navigation, not allowing sufficient draught of water. To prevent these deposits dredging is insufficient. According to General Morin, the best arrangement appears to be that which has been adopted in the lower part of the river Po.

Submersible dykes are formed on both banks of the river. The object of these is to protect against average floods the rich and fertile plains which are left in the greater bed of the river, and are called *golenes*. In order that the dykes in question may not prevent the waters of great floods from expanding over the whole width of the greater bed, it is prescribed that their top should be 1.50 meters below the great insubmersible dykes. These dykes, then, have the effect of narrowing the river in times when its waters are low, thus forming a channel, which M. Daussee calls a *duits*. Hence the velocity of the water is increased, having the effect of carrying off sand and gravel that would otherwise be deposited. In the floods of summer the waters of the river spread into the fluvian plains and fertilize them.

Similar dykes to those of the Po were formed on the Moselle in 1835, and by this means navigation is rendered possible between Metz and Frouard. At the mouth of the Somme the Compagnie des Chemins de Fer du Nord, by constructing dykes which have necessitated an expense of 515,000 francs, have succeeded in "conquering" from the ocean and transforming into cultivable land 502 hectares, representing a value of 1,740,000 francs.

The reporter points out, further, that the insubmersible dykes formed on the banks of great watercourses often occasion serious dangers, and he recalled the fact that in 1846 the Italian engineer, Paleocapa, when consulted as to the regularization of the course of the Theiss, had advised to leave between the dykes an interval of several hundred fathoms. His advice was not listened to; the dykes were constructed on the very banks of the river, and the terrible disaster of the town of Szegedin was the sad consequence.

En résumé, the large dykes should be placed five or six meters from the border of rivers and streams, so as to furnish to the inundation a space sufficient to extend itself in without danger.

MENTION was made in the "Minutes of Proceedings" Inst. C. E., vol. lvi., p. 337, in a communication on the Aubois lock, of a proposal to use a hydraulic brake for causing the pipes, in the apparatus for saving water in locking, to drop quietly on to their seats without any shock or rebound. This has since been successfully accomplished, without the aid of a valve, by employing a brake consisting of a wooden inverted truncated cone moving in a vertical sheet-iron cylinder filled with water. The cylinder is 1 foot 8 inches high, and 8 inches in diameter; it is fastened at the bottom to an iron plate firmly fixed on the ground, and has a sheet-iron lid. The upper part of the cone, which is cylindrical for a length of $\frac{5}{8}$ inch, has a diameter of $7\frac{1}{2}$ inches, and a length of 8 inches. An iron rod is inserted in the axis of the cone; it is fastened by a nut at the bottom, and passes through a hole in the center of the lid of the cylinder, and has a cord attached to it at the top. When the counterpoise of each great movable pipe of the apparatus approaches its highest point, the cord attached to the cone is abruptly pulled tight, and the descent of the pipe is checked by the resistance the cone experiences in rising in the cylinder. The cone is sufficiently weighted by the rod to sink to the bottom of the cylinder when the cord is slackened. By increasing the distance traversed by the cone, the fall of the pipe on to its seat can be rendered as easy as desired, without its tightness on its seat, when once reached, being at all affected.

BOOK NOTICES

MEDICAL CHEMISTRY. By C. GILBERT WHEELER. Second and revised edition Philadelphia: Lindsay & Blakiston. For sale by D. Van Nostrand. Price, $3.00.

The present work begins with a treatise on the classification of organic compounds as in the author's work on organic chemistry. This, with the discussion of alcohols, ethers, acids and alkaloids make up half the volume.

Then comes a brief discussion of the proximate constituents of plants, and this is followed by a similar treatment of the proximate principles of the animal organism.

The book will prove convenient for a student who desires to refresh his memory upon a point of chemical constitution, but the work is not designed to satisfy the complete wants of a medical student.

LIFE AND WORK OF JOSEPH HENRY. By FRANK L. POPE, Vice-President of the American Electrical Society, Member of the Society of Telegraph Engineers, etc., etc. Pp. 31. New York: D. Van Nostrand. Price, 50 cts.

This pamphlet is reprinted from the "Journal of the American Electrical Society," and it is especially interesting and useful as giving a clear account of Professor Henry's electrical and electro-magnetic investigations. We want

a more considerable work in relation to the career and influence of Professor Henry, but in the absence of such a volume this paper will prove most instructive.

THE INTER-OCEANIC CANAL QUESTION. By REAR ADMIRAL DAVID AMMEN, U. S. N. Philadelphia, L. R. Hammersly & Co. For sale by D. Van Nostrand. Price, $1.00.

This subject is of absorbing interest at the present moment. That the various aspects of the question are fully considered, may be inferred from the following list of topics presented:

The sufficiency of our information in relation to the topography of the American Isthmuses. —The feasibility of an Inter-Oceanic Canal via Lake Nicaragua, as a commercial question.— The present aspect of the ship-canal question. —Proceedings in the general session of the congress in Paris, May 23, and the technical commission, May 26, 1879.—Report of Rear Admiral Ammen to the Secretary of State, June 1879.—Report of Civil Engineer A. G. Menocal to the Secretary of State, June 21st, 1879.

Thus, in compact form by the most competent authorities, we have the question presented, which now commands the attention of people of many nationalities.

ANALYSIS NOTE-BOOK By W. B. POTTER. St. Louis: Buxton & Kinner. For sale by D. Van Nostrand. Price, $1.50.

This is simply a laboratory note book, for the purpose particularly of recording quantitative analyses.

The pages are headed with the names of common objects of commercial assay, and the possible constituents are neatly printed in column on the left side.

A table of useful multipliers, and one of atomic weights are thoughtfully added for convenience of the analyst.

LINKAGES. THE DIFFERENT FORMS AND USES OF ARTICULATED LINKS. By J. C. DE ROOS. Science Series No. 47. New York: D. Van Nostrand. Price, 50 cts.

The subject of this little book has not as yet, occupied the attention of American scientists. The literature of Linkages is mostly in the German, French, or Russian languages. This essay has appeared in several languages of Europe. The unique, and extensive applications of mechanical methods to solutions of problems, formerly supposed to lie beyond the reach of such processes, proves to be very attractive to a certain class of students who delight to be early in any new field of research, especially where there exists, as in the present case, a possibility of reward in the way of original discovery.

COMMON SENSE IN CHURCH BUILDING. By E. C. GARDNER. New York: Bicknell & Comstock. For sale by D. Van Nostrand. Price, $1.00.

Arguments for and against decorative architecture are presented here, in the form of letters from imaginary correspondents.

Aside from a tendency to prosiness on the part of most of the writers, and a stilted form of pictism on the part of a few, the arguments of people who have not thought deeply upon this or any similar subject are agreeably enough presented.

The book is in an exceedingly neat form, and contains in its practical portions some good illustrations.

MISCELLANEOUS.

WE regret to announce that owing to the late fire at Boston, by which the printing establishment of Rand, Avery & Co. was partially destroyed, the publication of Mr. Shunk's new work, "The Field Engineer," has been unavoidably postponed. The printed sheets having been destroyed, it will be necessary to print it off again entire.

THE most important news of the past month in the world of science in the announcement by Mr. Maclear, of the St. Rollox Works, Glasgow, made to the Philosophical Society of that city. In a note addressed to that body, Mr. Mactear said that after a series of careful experiments, extending over a period of thirteen years, he had succeeded in obtaining crystallized forms of carbon. They were perfectly pure and transparent, and had all the refractive power of diamonds. They had the crystalline form of diamonds, and resisted acids, alkalis, and the intense heat of the blow-pipe. They also scratched glass; and the only other tests that remained to be applied were as to whether they could scratch diamonds or be scratched by diamonds, as to the refractive index of the crystals, and also the measurement of the angle of the crystals. These tests had not, as he had said, been carried out, but they would be shortly, and he hoped to put some of the specimens before the Society on a future occasion. He had no doubt in his own mind, and neither was there any doubt in the minds of the scientific gentlemen (Profs. Tyndall and Smyth) whom he had consulted, that they were diamonds, but in the meantime he preferred to describe them as pure crystalline forms of carbon. The forms he had obtained were in size 1-32nd of an inch. They are in the hands of Mr. Maskelyne, of the British Museum, for rigid examination.

AN interesting paper on the discovery of ancient ironstone mines in the Cliviger Valley, Lancashire, and of the remains of old bloomaries in the immediate locality, was read by Mr. John Aitken at the meeting of the Manchester Geological Society on the 16th. The mines were of an extensive character, and had been skillfully laid out, but the period at which they had been worked could not have been less than two or three centuries back, as the entrances to them had been completely blocked up, and their existence almost forgotten in the neighborhood. The ironstone bands were similar in thickness but superior in quality to the well known Low Moor black band, and appeared to have been extensively got during the working of the mines. The remains of seven

bloomaries were discovered in the neighborhood from three to seven miles distant from the mines, and these undoubtedly existed at the time of the Roman occupation.

ENGINEERS often want to mount a photograph. The following makes a good paste for the purpose. Mix thoroughly 630 grains of the finest Bermuda arrowroot, with 375 grains of cold water, in a capsule, with a spoon or brush, then add 10½ ounces more water, and 60 grains of gelatine in fine shreds. Boil, while stirring, for five minutes, or until the liquid becomes clear, and when cold stir in well 375 grains of alcohol, and five to six drops of pure carbolic acid. Keep it in well-closed vessels, and before use work up a portion carefully with a brush in a dish. It will keep for considerable time.

THE highest inhabited houses in the world are, says the *Scientific American*, in this country; one, a miner's house on Mount Lincoln, Colorado, is 14,157th ft, high. Another in Peru, a railway village, called Galera, is 15,645 ft. high. Near this place is the celebrated railway tunnel of La Cima, which is being bored through the peak of the mountain. The tunnel is 3,847 ft. long, and is 600 ft. above the level of perpetual snow.

CAST iron magnets are made by M. Carré by melting soft metal very slightly carburetted in crucibles, adding 10 to 15 per cent. of steel filings, and running it into moulds. If 1 to 1½ per cent. of nickel be added to the mixture, and 25 to 30-1000ths of copper, or 2 per cent of tin, and 50-1000ths of copper, the moulded iron can be tempered at a cherry-red heat. The best result is obtained, however, says the *Electrician*, by tempering pure cast iron at as high a temperature as the moulded pieces will stand without distortion of fracture.

COLOGNE CATHEDRAL.—The *Cologne Gazette* says:—"The two towers of our cathedral are now the highest buildings on the earth; they exceed by 1.50 meters the tower of St. Nicholas Church, in Hamburg, which is 144.20 meters high. When completed they will measure 160 meters, reckoning from the pavement of the cathedral cloisters, or 157 meters reckoning from the floor of the church itself. The following are the heights of the most remarkable high buildings in the world:—Towers of Cologne Cathedral, 160 m. or 157 m. (524 feet 11 inches, or 515 feet 1 inch); tower of St. Nicholas, at Hamburg, 124.20 m. (473 feet 1 inch); cupola of St. Peter's, Rome, 143 m. (469 feet 2 inches); cathedral spire at Strasburg, 142 m. (465 feet 11 inches); Pyramid of Cheops, 137 m. (449 feet 5 inches); tower of St. Stephen's, in Vienna, 135.30 m. (443 feet 10 inches); tower of St. Martin's, at Landshut, 132·50 m. (434 feet 8 incnes); cathedral spire at Freiburg, 125 m. (410 feet 1 inch); cathedral at Antwerp, 123.40 m. (404 feet 10 inches); cathedral of Florence, 119 m. (390 feet 5 inches); St. Paul's, London, 111·30 m. (365 feet 1 inch); ridge tiles of Cologne Cathedral, 109.80 m. (360 feet 3 inches); cathedral tower at Magdeburg, 103.60 m. (339 feet 11 inches); tower of the new Votive Church at Vienna, 96 m. (314 feet 11 inches); tower of the Rathhaus at Berlin, 88 m. (288 feet 8 inches); tower of Notre Dame, at Paris, 71 m. (232 feet 11 inches)."

SOME interesting observations have lately been made on the influence of forests on rainfall, in the French School of Forestry, at Nancy. The results of these observations, made during the past six years, are summed up by the sub-director of the school as follows: (1) Forests increase the quantity of meteoric waters which fall on the ground, and thus favor the growth of springs and of underground waters. (2) In a forest region the ground receives as much and more water under cover of the trees than the uncovered ground of regions with little or no wood. (3) The cover of the trees of a forest diminishes to a large degree the evaporation of the water received by the ground, and thus contributes to the maintenance of the moisture of the latter and to the regularity of the flow of water sources. (4) The temperature in a forest is much less unequal than in the open, although, on the whole, it may be a little lower; but the minima are there constantly higher, and the maxima lower, than in regions not covered with wood.

JAPANESE industry is turning to channels well-known elsewhere. The paper mill at Kobe, Japan, belonging to Messrs. Walsh, Hall & Co., is—the *Times* says—working night and day, and turning out large quantities of paper, for which there is a ready sale in Japan and China. At Kobe also are the ironworks of E. C. Kint & Co., which are in full swing, making and repairing the small passage boats that are so numerous on the Japanese coast. A new line of steamers has been inaugurated between Yokohama and Hong Kong by the Japanese company of Mitsu-Bichi, each steamer calling at Kobe. At Sendji a new cloth factory has been started by the Government; but as the native supply of wool is but small, the raw material will have to come from Australia. Commercial civilization has, indeed, gone so far in Japan as to have produced a large issue of forged notes, supposed to have been executed in Germany, and set afloat in Japan through the connivance of Government officials there.

A CONTEMPORY says that writing ink may be prevented from rusting metallic pens by placing broken pieces of steel pens, or any small pieces of iron not rusted, in the bottle in which the ink is kept. The corrosive action of the acid contained in the ink will be expended on the iron introduced.

THE magnesian limestone or dolomite from Bolsover—with which the Houses of Parliament are built, and which has proved a valueless stone for building near the sea or in large towns, on a ccount of its affinity for hydrochloric and sulphuric acids—contains: Silica, 3.6 per cent.; carbonate of lime, 51.1 per cent.; carbonate of magnesia, 40.2 per cent.; iron alumina, 1.8; and water—and loss in analyzing —3.3 per cent.